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Version: Version of Record

Link(s) to article on publisher's website:

<http://dx.doi.org/doi:10.21954/ou.ro.0000f111>

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Holocene Environmental History and Palaeoecology of the Lizard Peninsula, Cornwall

A thesis presented for the degree of Doctor of Philosophy

By

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DATE OF SUBMISSION : 5 DECEMBER 2012

DATE OF AWARD : 5 JUNE 2013

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Abstract

The vegetational history and palaeoenvironments of the Lizard Peninsula are poorly understood with previous palynological research providing only fragmentary data from coastal sediments and inland palaeosols. In this study sediments from the plateau in the centre of the peninsula are analysed. This addresses questions regarding a possible preanthropogenic forest, the origins of the heathlands and the history of the endemic *Erica vagans* L.

Three sites were identified as having suitable pollen archives. The longest sequence has a basal ^{14}C date of 7489 ± 64 cal. years BP and provides firm evidence of a closed canopy birch/pine forest with hazel understory and a ground flora of ferns. There is evidence of a Mesolithic clearance phase before the rise of alder and oak at ca. 5175 ± 125 cal. years BP. This site is 50 m below and 4 km south of the high point of the plateau on Goonhilly Downs. The sequence here has a basal ^{14}C date of 4152 ± 254 cal. years BP and provides evidence of Bronze Age arable farming. This ceases at ca. 3000 years BP coinciding with evidence of cooler, wetter weather. Discontinuities in the sedimentary record at both sites interrupt the landscape reconstruction.

Iron Age arable farming and heathland is indicated at the lower site at ca. 2230 ± 82 cal. years BP with the heathland largely disappearing during the medieval period. The third site, on the edge of the Downs, indicates a predominantly heathland environment at ca. 1100 AD with some pastoral agriculture. Less than 100 years later there is unequivocal evidence of arable farming alongside heathland, and a shift from *Calluna* to *E. vagans* dominated heathland. The landscape remains stable until the 19th century when pine and later fir plantations are evidenced. Changes in the pollen assemblage in this agriculturally marginal area appear to reflect socio-political rather than climatic changes.

Acknowledgements

This thesis has been a very long time in the making and without the help of a large number of people who have kept the faith it would never have seen the light of day. Foremost among these are my supervisors who have been with me from the start, Charles Turner and James Scourse.

Since first meeting Charles at Luton Airport in 2003 he has been patiently supporting me through the sometimes overwhelming difficulties of working in isolation alongside a demanding job. He somehow had the knack of knowing when I needed help and coming up with the right solution. I am forever grateful for his hospitality when I was visiting the Cambridge quaternary labs and for taking me under his wing during field trips and conferences when the throngs of learned people could be a bit daunting. James turned up at my front door on a sunny Cornwall morning in spring of the same year. I had the first hint of his endless enthusiasm and masterful judgement when, while searching for suitable sites on Goonhilly Downs, he spotted a line of *Phragmites* cutting through the dry heathland. In a flash we were off with our auger and the rest is Bronze Age history.

When Charles retired from the OU Bob Spicer stepped in and quickly spotted that I needed a lift. He played 'good cop' when my long suffering long time supervisors were giving me dire warnings for my slow rate of data collection. He demonstrated a confidence in me that I hope has not been misplaced. I've had much other help from members of the quaternary community, Steve Boreham who welcomed me to the Cambridge labs and talked me through my first pollen diagram drawing programme, Rob Scaife and Keith Bennett who advised me on slide preparation and pollen identification at crucial moments and Chris Caseldine who agreed to my use of the Tremough campus laboratories. Of particular help over the past couple of years has been Michael Grant whose interest in my work has been followed by enormously valuable advice that has kept my writing-up on track. Very special

thanks must also go to Brian Long of Bangor who prepared most of my material for counting with great speed and effectiveness.

Massive thanks are due to the research department of Cornwall College who have paid for most of my carbon dates, field trips, conference visits and trips to Walton Hall. Their faith in the importance of research is heart warming. And to my colleague Bruce Forrest I cannot say thank you too many times. He has been a constant source of encouragement, provided pivotal support in the use my second stratigraphical computer programme and spent a hot exhausting day with me on Hendra mire collecting transect data. Yvonne Oates selflessly made her skills with GIS available to me, Mike Williams and Steve Brown were always prepared to talk me through anything with a mathematical angle and Michael Hunt was a great source of encouragement, anecdote, and science department funds when the research department closed its doors.

For allowing me access to the various sites on the Lizard Peninsula I'd like to thank Ray Lawman of Natural England, Robert Gilbert of Erisey Barton and Dennis Roberts, the owner of the Hendra mire site. All supported my scientific endeavours without hesitation.

Finally none of this could have been possible without the support of my wife Ntsebo. She has happily entertained all my supervisors when they have visited, a list that includes my early mentor and inspiration Judy Turner from Durham who came to wish me God's speed at the outset. Ntsebo has always been very positive towards this seemingly endless endeavour, never questioning the cost in time and money. She even allowed me, without a murmur, to hijack her holiday plans so we could visit Switzerland and the INQUA conference. I only hope I can do the same for her some day.

Thank you, thank you one and all.

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Chapter I INTRODUCTION

The Lizard Peninsula is one of the most important botanical areas in the British Isles (see section 1.3). It is designated as part of the Cornwall Area of Outstanding Natural Beauty and approximately 25% of the peninsula is managed for conservation. Natural England administers the 17 km² National Nature Reserve, there are two Cornwall Wildlife Trust reserves, three Sites of Special Scientific Interest and Predannack Downs and much of the coast is managed by the National Trust (Natural England 2010). It is designated under the EC Habitats Directive as a Special Area of Conservation (JNCC 2011). It also contains much important archaeological evidence dating back to the Mesolithic (see section 1.5). An understanding of the palaeoecology and environmental history of the peninsula is desirable as a tool to inform conservation decisions and archaeological reconstructions. It is the aim of the current study to add to our knowledge of this under researched dimension of this very important site. Of particular importance is the conservation of the heathlands and to assist this, an understanding of both the origins of the heathland and its dynamics are required.

To address our knowledge gaps regarding the palaeoecology of the Lizard Peninsula three specific research aims have been established.

- i. To determine the nature of the preanthropogenic landscape on the Lizard Peninsula plateau. More specifically to establish whether or not the plateau was forested and if so the nature of the forest.
- ii. To trace the origins and development of the heathland vegetation and to determine the extent of the human contribution to this development.
- iii. To gather evidence of the history of the endemic Ericaceae *Erica vagans* on the peninsula in order to inform the debate as to the origins of this species in the post Devensian recolonisation of the area.

As an introduction to this study the current literature has been sourced to provide an overview of the geology, soils and flora of the Lizard Peninsula. It has also been used to develop a picture of what is known of the environmental history of the southwest of the British Isles with particular reference to Cornwall and the Lizard Peninsula. Finally the literature concerning Holocene heathland development and palaeoclimates in the British Isles has been reviewed.

1.1 Geology and geomorphology of the Lizard Peninsula

The Lizard Peninsula is the southernmost region of the British Isles the surface of which is a Pliocene-Pleistocene wave cut marine platform (Balchin 1964), generally considered to be one of the best examples of an elevated platform in Britain (Flett & Hill 1946, p.3). With the exception of the valley bottoms there is very little ground below 60 m O.D. and its highest points are 115 m at Roskruge Beacon above St. Keverne and 112 m at Dry Tree on Goonhilly Downs. The peninsula rises very gently from the south to the north where it merges with the Meneage, a jumble of disrupted strata resulting from the Late Devonian thrust faults of the Lizard complex (see Fig. 1.1 below).

The origin of the geology of the Lizard Peninsula (Fig. 1.1), unique to the southwest, is generally ascribed to an intrusion episode during the late Carboniferous Hercynian (Variscan) orogeny (Bromley 1964) when a fragment of oceanic crust was faulted against Devonian sediments. The rocks of this intrusion, once thought to be of Cambrian or Pre-Cambrian age, are now considered to be an Upper Devonian ophiolite complex (Bristow 1996). The high-grade metamorphism that had suggested a much greater age than the Devonian rocks of the rest of Cornwall possibly resulted from their being thrust and faulted before they had cooled from their original igneous temperatures (Bristow 1996). They comprise of schists, metamorphosed from muds, sandstones, volcanic tuffs and basaltic lavas with later intrusions of first peridotite and then gabbro. The original peridotite transformed into three different types of serpentine that were themselves intruded by

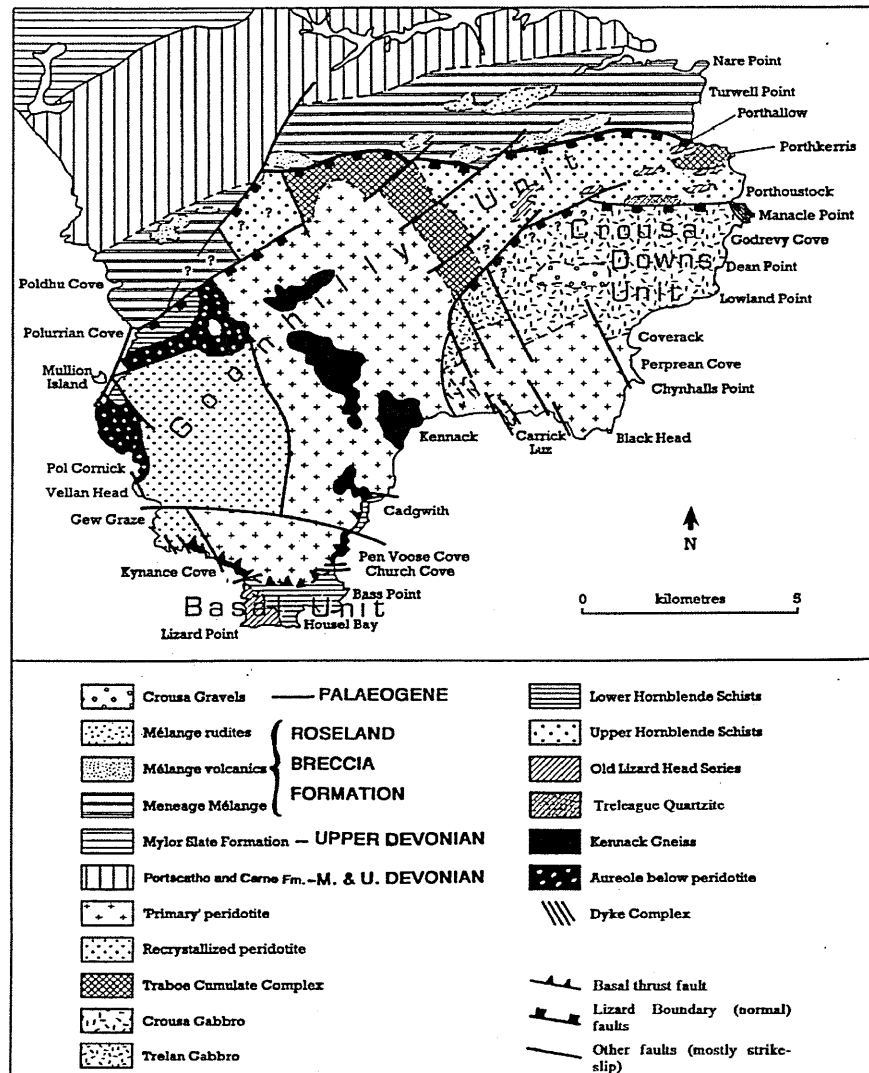


Figure 1.1 Geological sketch map of the Lizard showing the Basal, Goonhilly and Crousa Downs structural units. The 'primary' and recrystallized peridotite constitute the serpentine. (Map reproduced from Floyd *et al.*, 1993.)

dykes of gabbro and dolerite. Dykes of epidiorite, commonly known as 'Black Dykes', in turn, intruded the regions of gabbro (Flett & Hill 1946, pp.12-25, Edmonds *et al.* 1975). It appears that this geological complex was lifted and thrust against the Gramscatho Beds of the Devonian rocks to their north from either a single intrusion (Green, 1964) or as many as three (Bristow 1996). The Carboniferous-Permian Hercynian earth movements that thrust these two geological formations together produced a region several kilometres in length

from Pollurian to Porthallow, consisting of crushed and splintered rocks of various origin. This highly complex agglomeration of angular rocks is known as the Roseland Breccia Formation (Bristow 1996) and referred to by Flett and Hill (1946, pp.120-136) as the Meneage Crush Zone. Normal faulting that followed the Hercynian episode much later now marks the northern boundary of the Lizard complex (see Fig. 1.1).

Of the various rocks of the Lizard, the serpentine is by far the best known and, to a large extent, confers to the peninsula its most characteristic features of geology and flora. At 78 km² it is the largest serpentine outcrop in England and Wales and can generally be recognized by the relatively barren vegetation it supports compared to the more productive soils of the surrounding schists and gabbro. Chemical analysis shows it to be an ultra-basic rock with up to 36% MgO by weight. Calcium levels are very low at 0.07% to 2.36% of CaO but, unlike the other rocks in the region, there are significant traces of nickel, chromium, vanadium and cobalt oxides. The only other significantly basic rocks are the hornblende schist and the gabbro both with about 7% MgO and about 10% CaO (Flett & Hill 1946, pp.53, 60, 76).

The Crousa Gravels of Crousa Down above Coverack are of considerable interest to geologists consisting of about 0.5 km² of quartz-rich debris in an area dominated by gabbroic rocks (Ealey *et al.* 1999). Scourse (1985) conducted a palynological investigation that placed them in the Tertiary, probably Lower Tertiary.

The plateau is at its most level on the hard serpentine outcrops and parts of the gabbro. Here only the deeply incised narrow rocky valleys plunge below an otherwise almost uniform ca. 100 m O.D. These large areas of almost horizontal surface, particularly Goonhilly and Predannack Downs, frequently become waterlogged following heavy winter rains (Flett & Hill 1946, p.4). The remainder of the gabbro, and the gneiss, slate and schist outcrops, largely on the eastern side of the peninsula and on the Meneage, exhibit a more eroded ridge and valley topography. The western side of the peninsula, where the serpentine meets the sea, has the steepest and most spectacular cliffs (see Fig. 1.2). Those on the eastern side are more rounded in outline and have several Pleistocene raised beaches at their foot. The largest of these is at Lowland Point.



Figure 1.2 The serpentine cliffs and Pliocene plateau on the west coast near Kynance Cove (left) and the raised beach covered by Head and loess at Lowland Point on the east coast (right).

The drainage of the plateau has produced a broadly radial stream pattern. Their courses are, to a large extent, controlled by the geological structures over which they flow (Staines 1984). Flett and Hill (1946, pp.6-7) observe that the Kennack, Cadgwith and Poltesco streams, for example, follow less resistant granitic rocks bounded by serpentine outcrops. Those that drain to Porthoustock and Porthallow follow the gabbro-schist contact for part of their length. The origins of the markedly estuarine Cober and Helford rivers, however, are considered as almost certainly much more ancient, predating the final retreat of the sea from the platform. Other coves and valleys such as Poldhu, Gunwalloe and Porthleven, and the inland courses of many of the streams, have no obvious geological explanation.

The Quaternary geology of the Lizard is of particular significance for this study. Although there is no evidence that the ice of the glacial periods of the Pleistocene ever reached Cornwall (Bowen *et al.* 1986) the area was periodically subjected to a semi-arctic climate with permafrost and considerable periglacial activity. Flett and Hill (1946, pp.168-172) describe four significant features dating from the Quaternary. These are 'Head', raised beaches, buried forests and alluvium.

In the Late Pleistocene lithostratigraphic models described by Scourse (1996) (see Fig. 1.3) the Head is placed within the Penwith Formation (PF). It is a breccia consisting of angular

stones embedded in a very variable loamy matrix. The material is always of very local origin, usually unstratified and most has probably derived from freeze-thaw frost shatter and downslope movement by solifluction. Some, however, may be derived from rock-fall and scree deposits, others by mudflow or near-fluvial conditions. In some valleys and on some raised beaches it is up to 3 m thick and occasionally caps the cliffs on the east of the peninsula to a depth of 10 m or more. Thinner Head deposits are much more widespread, however, in particular over the Devonian slates to the northwest of the peninsula and on

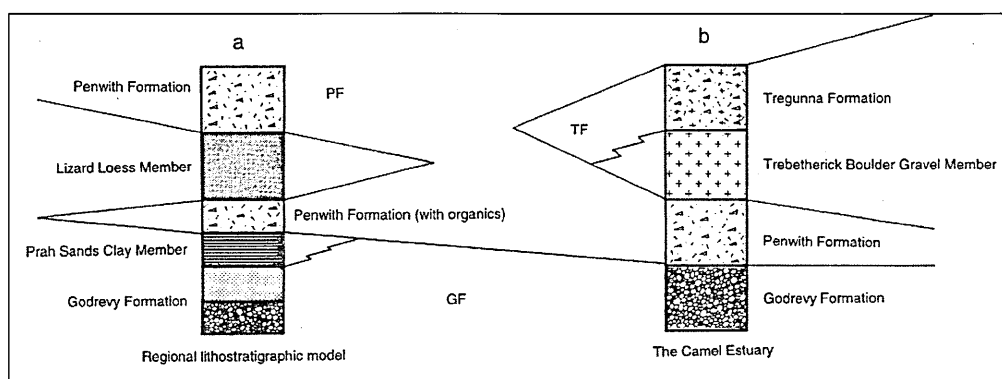


Figure 1.3 Lithostratigraphic models for Quaternary sequences in north and west Cornwall (from Scourse, 1996). GF: Godrevy Formation; raised beach sediments. PF: Penwith Formation; see text. TF: Tregunna Formation; confined to Camel Estuary, non-local material from river catchment.

the schists. They are rare over the serpentine and gneiss, particularly on the more heavily eroded west coast but there are usually some deposits, of variable thickness, over the gabbro. The Head deposits on the raised beaches of the east coast, particularly at Lowland Point, are unusual in that they often contain large boulders of gabbro. The constituents of the local hedgebanks suggest that such boulders may once have been common on the eastern gabbro outcrop (Staines 1984).

Raised beaches occur all around the coasts of the Lizard Peninsula but are best preserved on the eastern shore. Most are between 2 m and 5 m above present sea level and vary in width from a narrow shelf at the base of the cliff to a platform with a width of 50 m or more in. As explained above, they are typically covered in Head deposits, usually rather thin and often partially eroded away. The dating of these beaches can best be inferred from dating evidence from other raised beaches in southwest Cornwall. Radiocarbon dating of organic sand

within the raised beach at St. Loy on the Penwith peninsula, indicate that it must be older than the Middle Devensian (at least 30 ka BP). Aminostratigraphical and thermoluminescence dating suggest that other raised beaches in the region are from Pleistocene interglacial highstands (Scourse 1996, Scourse & Furze 2001).

The third of Flett and Hill's Quaternary features are the 'buried forests' that indicate more recent changes in relative sea level than the Pleistocene raised beaches. They describe evidence for these coming from the 'well known' remains of preserved roots and trees exposed following storms in the Falmouth Estuary and Mount's Bay, and from Rogers (1818) who described something similar in Porthleven Harbour. French (1999) provides a thorough review of the evidence for these 'submerged forests' around Cornwall noting evidence for them at Gunwalloe and Kennack Sands around the Lizard. It would appear that at the time these forests flourished the sea level was about 12 metres lower than at present, and that they were occupied by humans (Flett & Hill 1946, p. 171). Sea level changes in south-west England during the Holocene have been investigated by Heyworth and Kidson (1982). They show a rapid rate of sea level rise between ca. 10 ka to 6 ka BP from about 35 m to 8 m below the present level, with a much slower rate of increase since then. Using evidence from Marazion Marsh, Healy (1995) suggests that *local* sea and groundwater levels were much influenced by morpho-sedimentary structures, a position supported by the work of James and Guttman (1992) at Chyandour and French (1996) at Gunwalloe. French suggests that embayments may have provided a suitable environment for low lying forests, which may then have been inundated by the sea in single, brief episodes.

Alluvium, the final of the Quaternary features described by Flett and Hill, is confined to narrow strips along the larger streams. Only the Helford river and the Loe Pool have substantial deposits and these are believed to be recent, accelerated by mining and still forming. O'Sullivan (1999) has suggested that haematite-rich mine waste carried down by the River Cober from its heavily mined catchment area is responsible for much of the Loe Pool sedimentation and may have decreased the permeability of the Loe Bar, increasing the frequency of flooding in recent years.

A particular area of interest in the Quaternary history of the peninsula has been the occurrence of wind-blown loess deposits (Coombe *et al.* 1956, Catt & Staines 1982, Roberts 1985). These constitute the Lizard Loess Member of Scourse's 1996 lithostratigraphy that interbeds with the Penwith Formation. These deposits vary from a few centimetres up to 2.5 m in depth and are most frequently found on the relatively level surfaces of the serpentine, with lesser deposits on the gabbro. Catt and Staines (1982) explain this distribution as resulting from differential rates of erosion during the Late Devensian and Early Holocene. The Cornish loess has been dated by Wintle (1981) as Late Devensian, 18 ka BP, and an analysis of particle size and mineral composition suggests its most likely origin as the glacial outwash deposits of the southern part of the Irish Sea basin (Catt & Staines 1982).

1.2 Soils of the Lizard

The different rock types of the Lizard Peninsula show greatly varying depths of weathering, this having a direct bearing on their soil formation. Staines (1984) describes the shales as not showing very intense weathering with an average depth of rotted, penetrable material of about 60 cm. The schists show a similar pattern but with a much higher proportion of more deeply weathered rock comparable with the gabbro and gneiss. The gabbro is observed as being frequently rotted to about 3 or 4 m below the surface and the gneiss only very slightly shallower. The serpentine, however, is observed as being less deeply penetrable with a thickness of weathered material between 0.5 and 1.5 m although where the serpentine is banded with granite-gneiss the depth can exceed 2 m.

The present soils of the Lizard peninsula have been thoroughly mapped by Staines (1984) as part of the Soil Survey of England and Wales. The soil survey map indicates quite clear soil group types related to the underlying rock types. These soil groups are listed below, the nomenclature is according to Staines (1984), see Appendix IX.

- 1 The Devonian shales and the schists to the northeast of the peninsula and the Meneage have a covering of *brown earth soils*. These are largely *typical brown earths* with no gley features, being friable and well aerated so well drained. Areas

with a tendency to waterlogging or with a high water table have *stagnogleyic* and *gleyic brown earths*. The *stagnogleyic* brown earths have a coarsely structured loam or clay subsoil that is slowly permeable. The *gleyic* brown earths are more permeable.

- 2 The most characteristic feature of the gabbro outcrop are the *paleo* and *cambic stagnogley* soils, often covered with large gabbro rocks and boulders that interfere with cultivation. These are non-calcareous soils with slowly permeable and impermeable lower horizons producing a distinctly gleyed topsoil. Other regions of the gabbro have *cambic* and *humic gley* soils, soils with permeable lower horizons but gleyed by groundwater. Cambic gleys have non-humose topsoils, humic gleys humose or peaty topsoils.
- 3 The area of granite-gneiss and mixed serpentine and granite-gneiss to the north of Lizard village shares a very similar soil covering to the serpentine (see below) although the granite-gneiss outcrops are predominately topped by *brown earths*. These are more or less gleyed according to the drainage properties and the influence of groundwater.
- 4 The soils of the serpentine are ultrabasic and non-calcareous and largely *cambic* and *humic gley* soils similar to those found on some regions of the gabbro (see above). There is some regional variation, however, with areas of *gleyic brown earths* on the eastern outcrop south of Coverack and pockets of *brown* and *stagnogleyic rankers* around the coast of the southwest outcrop. These are thin (<40 cm), lithomorphic, clifftop soils, the *brown rankers* showing no evidence of gleying whilst the *stagnogleyic rankers* are gleyed as a result of seasonal waterlogging on the more gentle slopes above the impervious rocks.

1.3 Extant flora of the Lizard

The flora of the Lizard Peninsula has long been the object of botanical interest. Coombe and Frost (1956) report John Ray describing the 'plentiful' distribution of *Erica vagans* L. in 1667,

and C.A. Johns in 1848 describing many of those species confined to the Lizard or very rare elsewhere in the British Isles. The rare flora of the Lizard is now well documented (e.g. Hopkins, 1984; Fitzgerald 2000) and include the clovers *Trifolium bocconeii* Savi, *T. incarnatum* ssp. *molinerii* (Hornem.) Ces. and *T. strictum* L., *Herniaria ciliolata* Melderis (rupturewort), *Genista pilosa* L. (hairy greenweed), *Cicendia filiformis* (L.) Delarbre (yellow centaury), *Allium schoenoprasum* L. (chives), *Hypochaeris maculata* L. (spotted cat's ear), *Ranunculus tripartitus* DC. (three lobed water crowfoot), *Pilularia globulifera* L. (pillwort), and *Juncus capitatus* Weigel and *J. pygmaeus* Thuill (dwarf and pygmy rushes). *Isoetes histrix* Bory (land quillwort) was one of the last of these rarities to be described, less than 100 years ago.

The concentration of so many rare species on the peninsula is considered by Hopkins (in Staines 1984) to be most likely '...due to the combination of a varied and unusual solid geology, an exceptionally mild oceanic climate and a topography unique in Cornwall' (p.20). These, he suggests, have produced a wide range of habitats from the perennially wet valley bottoms to the drought prone rocky outcrops and cliff tops. Recent work (e.g. Burden, 2001) suggests also that the poorly draining nature of much of the plateau, particularly over the serpentine, and the historical heavy use of the rutted track-ways during farming activities, has resulted in the preponderance of 'temporary pools'. These are now understood to be an essential habitat for an assemblage of specialist species including land quillwort, yellow centaury, the dwarf and pygmy rushes, three lobed water crowfoot and pillwort, and conservation efforts have now been directed to preserving these previously overlooked habitats (Fitzgerald, 2000; Biggs et al., 2001).

The heath vegetation of the Lizard is of particular interest because of the occurrence of *Erica vagans* in its only site in Britain. The acidic, base rich soils produce an unusual assemblage of acidophilous species such as *Calluna vulgaris* (L.) Hull (ling), *Erica cinerea* L. (bell heather) and *Potentilla erecta* (L.) Raeusch (tormentil) alongside such calcicolous species (basicoles) as *Filipendula vulgaris* Moench (dropwort), *Serratula tinctoria* L. (saw-wort) and *A. schoenoprasum* (chives). In their 1956 study Coombe and Frost looked particularly at the heath communities growing on the serpentine regions of the peninsula. They observed ten species that dominate the physiognomy and structure of the heaths. These are:

<i>Agrostis curtisii</i> (setacea) Bristle bent	<i>Festuca ovina</i> Sheep's fescue
<i>Calluna vulgaris</i> Heather (ling)	<i>Molinia caerulea</i> Purple moor grass
<i>Erica cinerea</i> Bell heather	<i>Schoenus nigricans</i> Black bog rush
<i>E. tetralix</i> Cross-leaved heath	<i>Ulex europaeus</i> Gorse
<i>E. vagans</i> Cornish heath	<i>U. gallii</i> Western gorse

Of the many possible combinations of these ten species they identified four of ecological significance. Each was related to a particular soil type (Coombe and Frost, 1956).

The first of these they called 'Rock Heath', dominated by *Festuca ovina* L. and *Calluna vulgaris*. This conforms most closely to the *Calluna vulgaris*-*Scilla verna* Huds. maritime heath community description (H7) of the National Vegetation Classification (NVC) (Rodwell, 1991) and occupies the shallow, coastal *brown ranker* soils. They found this community to be best developed on the exposed west coast of the peninsula, particularly around Mullion and Kynance Coves. A high diversity of annual and biennial species includes *Erica cinerea*, *Plantago maritima* L., *P. lanceolata* L. and *Lotus corniculatus* L. as constants with an *Armeria maritima* Willd. subcommunity on the rocky cliff-tops. *E. vagans* is scarce here, probably as the result of the degree exposure rather than the soils (Marrs and Proctor, 1978).

The second grouping they named 'Mixed Heath' dominated by *Erica vagans* and *Ulex europaeus* L. This conforms very closely to the H6 community description of the NVC. It occurs on a variant of the Rock Heath soil described as deeper, well drained *brown earths* and *rankers* that correspond to the *brown earths* in various stages of transition to the *stagnogleyic rankers* of Staines (1984). *Erica cinerea*, *Ulex gallii* Planch., *Viola riviniana* Rchb., *Filipendula vulgaris* and *Carex flacca* Schreb. are constants. The Mixed Heath is found on the western outcrop along the sides of coastal valleys and on rocky slopes sheltered from the westerly winds. It also occurs locally inland where the serpentine is close to the surface, particularly on Goonhilly Downs. A total of 143 species have been recorded but there is considerable variation between stands, ranging from open communities in the more exposed locations to older stands closed by a heather and gorse canopy. The community persists on

soils where drainage is impeded, but *Ulex europaeus* L. becomes scarce or absent.

The third grouping they named 'Tall Heath' dominated by *Erica vagans* and *Schoenus nigricans* L. This community is more homogenous and corresponds to the H5 community description of the NVC. *Molinia caerulea* (L.) Moench is also a co-dominant and for the first time *Erica tetralix* is a constant as is the basicole *Serratula tinctoria* L. (saw-wort). Bryophytes and lichens are relatively scarce. This community is found on wet, gleyed soils, the 'gleyic brown earths' of Staines (1984), and is particularly common on Goonhilly Downs where it forms a tussocky structure with open channels or 'pans' between. These areas also support *Sanguisorba officinalis* L. (great burnet), *Succisa pratensis* Moench (devil's bit scabious) and *Carex pulicaris* L. (flea sedge). In peaty areas *Phragmites australis* (Cav.) Steud., *Eriophorum angustifolium* Honck. (common cotton grass) and the insectivorous *Drosera rotundifolia* L. (sundew) and *Pinguicula lusitanica* L. (butterwort) occur.

The final grouping identified by Coombe & Frost is the 'Short Heath' with six co-dominants and corresponding to the *Ulex gallii*-*Agrostis curtisii* heath community (H4) of the NVC. In addition to *U. gallii* and *A. curtisii* Kerguelen (the bristle leaved bent) the other co-dominants are *Calluna vulgaris*, *Molinia caerulea* (L.) Moench, *Erica cinerea*, and *E. tetralix* L.. *Potentilla erecta* is a constant. It is distinguished from the other communities by the absence of *Festuca ovina*, *Schoenus nigricans* and *Ulex europaeus*. It is also the only one of the communities with a relatively frequent occurrence of bryophytes and lichens. This community is characteristic of acidic humic gley soils incorporating high levels of loess. Marrs and Proctor (1978) suggest that the great rarity of *Erica vagans* here might result from the low level of bases in the non serpentine derived soil. Short Heath occurs over large areas of the plateau, both over serpentine and gabbro, but is absent from the coastal areas and valleys.

The Rock Heath and Short Heath communities have affinities elsewhere in the British Isles and the western seaboard of France. Further studies (see Rodwell, 1991, pp. 441-442) have shown that communities similar to Rock Heath exist along most of the western coasts of the British mainland, the outer islands, the eastern and northern coasts of Ireland and the rocky coasts of Brittany and southwest France. The Lizard Rock Heath communities also have

strong affinities with some inland heaths. Short Heath is found throughout the southwest peninsula and part of South Wales (Rodwell, 1991). On the Lizard it is the *E. tetralix* sub community that dominates. The *E. cinerea* and *Festuca ovina* sub communities are found on the more freely draining soils to the east of its range where it finally transforms to the *Ulex minor*-*A. curtisii* (H3) heath of southern Dorset and Hampshire.

The Lizard NVC Project, stage 1 (Wilkins 2003) recognises three of these four heathland communities to be the most widespread flora assemblages on the peninsula. Tall Heath (H5) occupies a total of 773 Ha, Short Heath (H4) 450 Ha and Mixed Heath (H6) 235 Ha. The only other community covering a substantial area is WI scrub (*Salix cinerea*-*Galium palustre*) that covers an area of 67.5 Ha. The coastal Rock Heath (H7) covers 23 Ha.

The cliff-top vegetation of the Lizard has been thoroughly described by Malloch (1971) and Hopkins (1983). This is summarised by Hopkins in Staines (1984, pp.24-26). He notes that the large number of vegetation types observed occur on the full range of Lizard rocks, suggesting that soil depth and the degree of exposure to salt spray are more important factors than parent rock. The rock crevices and lower cliff slopes are characterised by the highly maritime *Armeria maritima* Willd. (sea thrift), *Crithmum maritimum* L. (samphire), *Spergularia marina* (L.) Griseb. (lesser sea-spurrey) and *Aster tripolium* L. (sea aster) community (MC1). On the cliff-tops and seaward of the Rock Heath are species-poor grasslands. *Festuca rubra* L. (MC8) dominated grassland gives way further inland to a more tussocky and species diverse MC9 grassland dominated by *Holcus lanatus* L. and *Dactylis glomerata* L. Woodland plants such as *Hyacinthoides non-scripta* (L.) Rothm. (bluebell) and *Silene dioica* (L.) Clairv. (red campion) are found in more sheltered spots and sometimes forming the ground flora of cliff scrub communities dominated by *Prunus spinosa* L. (blackthorn) and *Ulex europaeus* (gorse) (W22). Scattered throughout these communities are areas of thin, rapidly draining soils in which *Plantago coronopus* (buck's-horn plantain), *Sedum anglicum* Huds. (English stonecrop) and *A. maritima* have the highest constancy. These areas carry the maritime therophyte community (MC5) with abundant therophytes including *Bromus hordeaceus* ssp. *ferronii* (Mabille) P.M. Sm. (soft-brome) and *Desmazeria marina* (darnel pea).

Peaty soils on both gabbro and serpentine in the valley floors of Kynance, Main Dale and

Goonhilly are dominated by *Cladium mariscus* (L.) Pohl (fen sedge) with *M. caerulea*, *Galium uliginosum* L. (fen bedstraw), *Eupatorium cannabinum* L. (hemp agrimony) and *Shoenus nigricans* L. (black bog rush) occurring in the shallower peat (W24a). Other wet sites are dominated by the *Phragmites australis* (common reed), *Oenanthe crocata* L. (hemlock water dropwort) or *Juncus* spp. The valley bottoms at Gunwalloe and Poldhu have extensive reed beds. Other wet sites have Willow Carr (W1) dominated by *Salix cinerea* ssp. *oleifolia* Macreight (grey willow). South of the Lizard-Meneage boundary there are only small areas of woodland, mostly on base-rich rocks and dominated by elm. These appear to have arisen from planted elms since they are almost invariably close to settlements. North of the boundary, however, many of the valleys draining into the Helford river are wooded. The occurrence of beech and pine and other conifers suggest that these woodlands are planted, but the presence of coppiced oak, and some rich epiphytic lichen assemblages suggest more ancient woodlands (Hopkins, in Staines, 1984).

1.3.1 *Erica vagans* and the Lusitanian debate

The 'New Atlas of the British and Irish Flora' (Preston et al., 2002, p.293) shows *Erica vagans* as endemic to the Lizard peninsula on the mainland of the British Isles. It also occurs in Co. Fermanagh, Ireland, although this is a possible prehistoric introduction (Curtis & McGough, 1988), and is an important component of the Armorican heaths of the Brittany peninsula and the Sorian heaths of north central Spain (Devilliers & Devilliers-Terschuren, 1996). The sketch distribution map below (Fig 1.4) summarises these data. An explanation for the disjunct distribution of this species, along with other similarly distributed species, forms part of the ongoing 'Lusitanian' debate.

The abundance of *E. vagans* in the Mixed and Tall Heath communities of the Lizard is thought to result from the high levels of exchangeable cations, especially calcium and magnesium, in the serpentine derived soils which support them (Marrs & Proctor, 1978). Since *E. vagans* is not confined to the serpentine soils of the peninsula, the distinctive climate is also thought to be a significant factor (Proctor & Woodall, 1971). However, these preferences are insufficient to explain its endemic status on the peninsula as it occurs as an alien in many

sites throughout southern England (Preston *et al.*, 2002), nor its disjunct European distribution. A recent study for the HEATH project in West Cornwall (Forster *et al.*, 2011) has found what is almost certainly *Erica vagans* pollen in late glacial deposits (ca. 14000 years BP) at Carnmenellis, and in West Penwith in late Mesolithic/early Neolithic times (ca. 5620-5440 cal. years BP). This adds important evidence for the solving of the problem that has attracted a great deal of attention over the years, linked as it is with other British and Irish species of both flora and fauna with a similar disjunct distribution.

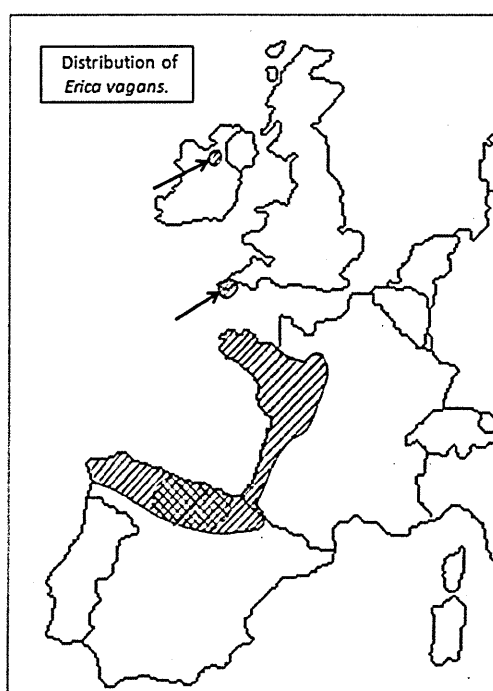


Figure 1.4 Sketch map showing distribution of *Erica vagans* (hatched area). Cross hatching indicates area of greatest abundance.

Godwin (1975) links *Erica vagans* with a number of other species as the Lusitanian-Mediterranean element of the flora of west and southwest Ireland, and to a lesser extent, southwest England. This assemblage is also known as the Hiberno-Cantabrian element (Heslop-Harrison, 1953) and Atlantic distributed species (Webb, 1983). The Ericaceae are well represented in this group and include *E. mediterranea*, *E. mackaiana* Bab., *E. ciliaris* L., *E. erigena* R. Ross, *Daboecia cantabrica* (Huds.) K. Koch and *Arbutus unedo* L. alongside *E. vagans*. All show marked discontinuities of range, centring on Portugal and northern Spain and

frequently extending northwards along the Atlantic coasts of France, in addition to their localities in Britain and Ireland. The developing views of the problem have been informed by an increasing understanding of Quaternary geology, by earlier Pleistocene records particularly those of the Hoxian, and most recently by DNA evidence.

Mitchell and Watts (1970) cited evidence for the presence of many of these species in the Irish Gortian (Hoxian) flora to support the view that they survived the last glacial period in proximal refuges on the western fringes of the European landmass, possibly in promontories whose climate was moderated by the North Atlantic Current. Pennington (1974) and Godwin (1975) opt for recolonisation in the Holocene as a result of migration along now submerged coastal fringes in the very early postglacial. Webb (1983) regards glacial refugia for Atlantic species in Ireland to be 'less unlikely' than alternative explanations in view of the difficulties associated with both long distance transport, and the suggestion that current populations have been isolated from a continuous early post glacial Atlantic distribution. Preece *et al.* (1986) analysed tufa deposits from Co. Dublin and concluded that there was 'unequivocal' evidence that the assemblage of mollusca identified had migrated to Ireland in the early post glacial. The means and exact pathway of their migration could not be deduced, however, and this molluscan migration contrasted unhelpfully with the failure of vertebrates, potentially more mobile animals, to also migrate from Britain.

Coxon and Waldren (1995) in their discussion of the biogeography of the Irish flora reviewed the evidence for the postglacial migration of the Lusitanian element. They noted that most of the Irish Atlantic species are either local or rare and although growing in largely coastal locations are not strictly coastal species. They discuss, in detail, the mechanisms by which these species may have survived glaciations *in situ* or in proximal refuges but, importantly, also point out that a single explanation for the distribution of all the Atlantic species is very unlikely. They cite the work of Foss and Doyle (1988, 1990) who used SEM images to separate the Ericoid pollen of the Irish Atlantic species. Using this technique they have shown that *Erica erigena*, a species usually considered as part of the Atlantic element of the Irish flora, first appears in 1431 AD which would suggest that it is a medieval introduction. Coxon and Waldren (1995) refer to the existence of many trading routes between Ireland and SW Europe at this time, an avenue that may have been responsible for

other local components of the modern Irish flora. Ericaceous species were frequently used in Spain as packing for wine and as animal bedding and *E. erigena* is currently planted around religious sites in Spain (Foss & Doyle, 1988).

Support for the theory of postglacial recolonisation from distant southern refugia comes from the most recent studies of the last British-Irish ice sheet (BIIS). Serjup *et al.* (2005) place the most southerly limit of the BIIS as totally covering Ireland and extending well into the North Atlantic with ice streams advancing as far as the continental shelf break. Using the ice-rafted detritus data from sediment cores from the NE Atlantic, Scourse *et al.* (2009) postulate that this maximum extent of the last BIIS occurred at 24 ka BP. It was followed by a rapid retreat but then a readvance between 22 and 16 ka BP. Proximal refugia for the Lusitanian flora during the Devensian must therefore be considered as highly unlikely.

It is evident that certain plant taxa have survived along the more southerly western edges of Europe, possibly throughout the Pleistocene, recolonising the deglaciated areas during temperate periods, (Coxon & Waldren, 1995). With our current knowledge of sea-level changes and land-bridge formation and destruction, however, the exact mechanism and timing of these events remains unexplained. Greater understanding of isostatic deflection as ice sheets recede (e.g. Lambeck, 1995; Wingfield, 1995), and further analysis of organic sediments on the continental shelves along the western rim of Europe, may be needed in order to progress this discussion. Recently though, evidence from DNA has been adding a new dimension to the debate.

Mitchell (2006) in his study of the post glacial migration of Irish trees uses both palynological and genetic evidence (haplotypes) to demonstrate that the principal tree taxa migrated from the south avoiding Britain, so the need for the trees to cross the Irish Sea is removed. The rate of migration suggested that biotic and abiotic vectors must have been involved but the nature of these will be difficult to establish. Clearly, though, this has implications for the migration of the Atlantic element of the Irish flora. Kingston and Waldren (2006) have used a 'genetic fingerprinting' technique (AFLP) to provide evidence for the origins of the Lusitanian Ericaceae *E. mackaiana* and *Daboecia cantabrica*, in Ireland. This suggests that the two species may have arrived by postglacial long distance transport along a more westerly

coastline that linked the British Isles with the west coast of France. This makes the anthropogenic introduction and glacial refugia explanations less likely. They point out, however, that the Spanish and Irish populations of a third species examined, *E. erigena*, appear to be more closely related and so more recently separated, supporting the findings of Foss and Doyle (1990).

Two areas of genetic evidence from completely different sources provide an interesting new insight into the apparently fluid gene flow along the western edge of Europe during and immediately after the Pleistocene. In his book ‘The Origins of the British’ Stephen Oppenheimer (2006) uses genetics, linguistics and archaeological records to show that the ‘Celts’, the people of Ireland, Wales, Cornwall and Scotland, migrated from the south along the Atlantic coast immediately after the retreat of the Devensian ice sheets from ca. 15 Ka BP.

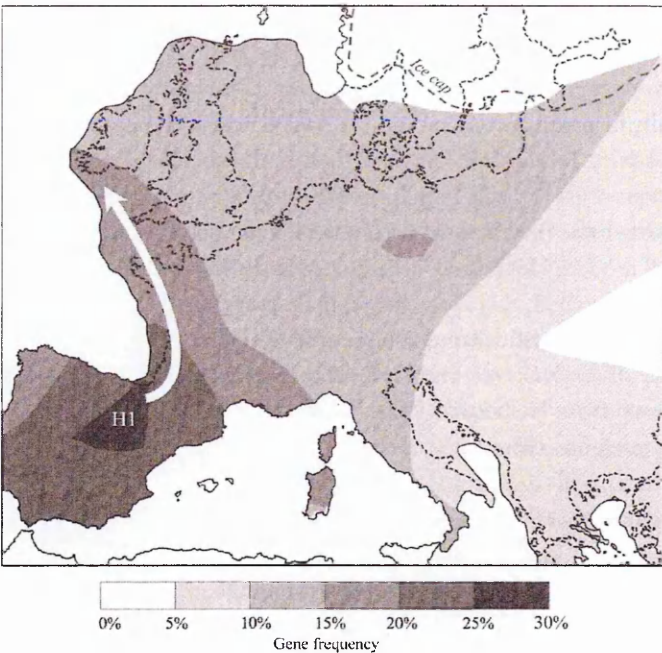


Figure 1.5 Contour map of the H1 human maternal sub-group gene frequency in Europe. The arrow indicates the direction of gene flow based on the gene tree. This also indicates that most of the expansion occurred in the Late Upper Palaeolithic. (from Oppenheimer, 2006)

Fig. 1.5 above shows the maternal H1 (Helina main sub-group) gene frequency across Europe. This sub-group is judged by gene trees to have expanded north in the Late Upper

Palaeolithic and today constitutes about one quarter of current maternal lines (p.132). The arrow, which incidentally closely follows the possible route of the Lusitanian plant species, indicates the direction of gene flow based on the gene tree and geography. Tracing the paternal line with the Y chromosome produces a similar picture (p.133). In a very recent study Edwards *et al.* (2011) have sampled brown bear and polar bear matriline over the past 120,000 years right across their present circumpolar range. Their reconstruction is punctuated by dramatic dispersal events governed by climate change and frequent genetic exchange when species ranges overlap. Of particular interest is the likely hybridisation of polar bears with the now extinct Irish brown bear. The gene trees indicate that this may have occurred most recently about 35,000 years ago. Although much earlier than the possible most recent migration events associated with the Lusitanian species it nevertheless provides a dramatic demonstration of the mobility of species during the Pleistocene.

In summary recent DNA evidence and evidence of the extent of the last BLS appear to lend strong support to the theory of postglacial long distance migration of the Lusitanian species from the south and in particular from the Iberian peninsula. It suggests that the magnitude and speed of these events may have been underestimated in the past as Coxon and Waldron (1995) pointed out in their conclusions. Genetic evidence also indicates that anthropogenic introductions may explain the distribution of some of these species but northern glacial refugia are becoming an increasingly unlikely explanation.

The focus of most of the research on the Lusitanian flora has been the west coast of Ireland but the disjunct distribution of the endemic *Erica vagans* of the Lizard Peninsula still requires an explanation. This ongoing debate is getting closer to providing the answer.

1.4 Environmental history of Cornwall

The palaeoenvironmental record from Cornwall, and the southwest generally, is less extensive than from other highland areas of the British Isles. This is despite the humid oceanic climate and the large areas of acidic bedrock, both conducive to the acidic, anaerobic conditions in which plant macro- and microfossils are preserved. The principal

reason for this is the lack of glacial activity in the region at any point during the Pleistocene and therefore the absence of over-deepened basins in which lake sediments or deep peats may develop (Caseldine, 1980). In addition, blanket bog in Cornwall is rare, due to the relatively low altitudes of the moors, and, where it does exist, it is fragmentary and rather thin. Valley peats do occur but these tend, again, to be rather shallow and it is usually very difficult to relate the palynological evidence within to the wider environment (Caseldine, 1980).

1.4.1 Late Devensian, Early Holocene

Despite these limitations the late Devensian and Holocene vegetation of Cornwall has been elucidated in a number of studies with most of the early evidence coming from Bodmin Moor. Of particular importance is the work of Conolly *et al.* (1950) and Brown (1977). Sediments principally from Hawks Tor, Dozmary Pool and Parsons Park (Fig. 1.6) have been used to construct a sequence of vegetational events from the late Devensian up until ca. 3000 BP.

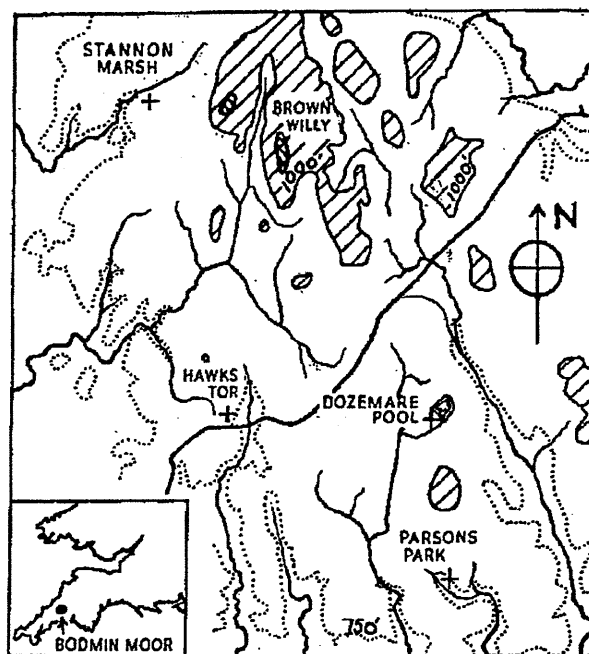


Figure 1.6 Sketch map showing Hawks Tor, Dozmary Pool and Parsons Park on Bodmin Moor (from Conolly *et al.*, 1950).

The oldest sediments are from Hawks Tor with an uncalibrated radiocarbon date of 13088 ± 300 years BP (15776 ± 1081 cal. years BP). However, root penetration, particularly at the higher levels, suggests that the dates should be seen as a minimum age only. Indeed, Brown (1977) believes that the nature of the pollen assemblages in this earliest sample appear older than the radiocarbon date suggests. More recent work by Simmonds *et al.* (1987) finds non-sequential radiocarbon dates in the lower layers (258-203 cm) of a Dozmary Pool core further reducing the confidence that can be placed in the vegetational sequences constructed. Correlation with the pollen zones of Godwin (1975) and the chronozones of West (1970), however, suggest that the stratification of the pollen may be more reliable than the most recent radiocarbon dates would infer. The evidence from deposits after ca. 5000 BP is poor, and without the benefit of radiocarbon dates. Vegetational reconstructions based on these are therefore very tentative (Brown 1977).

The earliest deposits are dated as those of the late glacial and their pollen evidence indicates open grassy heath vegetation, with the development of juniper scrub by 12000 years BP. This was followed by the spread of scattered birch woodland, probably in the valleys, with an increase in the ericaceous cover of the hillsides. At ca. 11000 years BP the birch carr disappeared, as evidenced by tree stumps at Hawks Tor. A reversion to herb-poor mire in the valleys and moss and lichen heaths on the hilltops was followed by the return of widespread snowbeds and solifluction deposits in the valleys by ca. 10500 years BP. By 10000 years BP juniper scrub with *Empetrum* heath had returned to the hillsides and upland areas, and *Sphagnum*/sedge mires are evidenced in the valley bottoms. As the climate became warmer, birch copses and hazel/oak scrub began to invade the hillsides and birch/willow carr establish in the valley bottoms, later giving way to some raised bog. After 9000 years BP the climate was apparently drying and warming sufficiently for the establishment of scattered oak/hazel woodland, with the first evidence of elm, on the hillsides, and grassland and heather moor on the uplands. The area of bog in the valley bottoms probably reduced at this time being replaced by grassland (Brown 1977).

Further drying and warming over the next two thousand years saw the persistence of the oak/elm/hazel woodland on the valley sides with extensive invasion of ivy and honeysuckle towards the end of the period, indicating average summer temperatures of about 13°C.

Grassland persisted in the valley floors and on hilltops, where it shared the area with heather moor. Even the basin at Dozmary Pool supported birch-willow carr for a while until damming appears to have renewed the growth of the bog. By ca. 7000 years BP extensive fires are in evidence before increasing wetness and cooling saw the penetration of *Alnus* into the woodlands and an expansion of the raised bogs and alder carr in the valley bottoms and depressions. Throughout the next 3000 years there is little evidence of extensive change in the vegetation of Bodmin Moor. Brown (1977) suggests that tall oaks may have established on the more sheltered hillsides while the exposed areas were colonised by more scrubby oaks and extensive hazel scrub. The relatively low arboreal pollen percentages, seldom exceeding about 60% of the total pollen, suggest a relatively low level of forest cover on the Moor, possibly suppressed by the exposure to the south westerly air flows of the peninsula (Caseldine, 1980). There is evidence of much denser oak wood in the surrounding lowlands, however, particularly to the south east, with more frequent occurrence of elm, ash and lime with some hornbeam. This period coincides with the colonisation of the area by hunting Mesolithic people who appeared to have minimal impact on the environment.

A Late Devensian pollen archive from closer to the current study site in West Cornwall has recently been investigated as part of the HEATH project (Forster *et al.*, 2011). The basal 30 cm of a monolith from Lower Lancarrow in Carnmenellis has been dated to cover the period between 13870 and 13200 cal. years BP. The pollen data show a late glacial tundra like flora in the lower part of the profile dominated by herbs, with tree and Ericaceae pollen increasing towards the top. The tree pollen is dominated by willow and birch, the latter including the dwarf birch, *Betula nana* as well as *B. pubescens* and *B. pendula*. The Ericaceae pollen is dominated by *Erica ciliaris*-type, almost certainly *E. vagans*, alongside *E. tetralix* and *Calluna vulgaris*.

1.4.2 The human impact on the vegetation

From ca. 5000 years BP the impact of humans on the vegetation of Bodmin Moor becomes more apparent as the Mesolithic gives way to the Neolithic. Although there is insufficient *Ulmus* pollen to detect an Elm Decline, Brown (1977) detects evidence for the expansion of

the grass/heather moorland on the summits that he links to possible Beaker people immigration. At ca. 2500 years BP decreasing hazel and a marked increase in *Plantago lanceolata* is interpreted as the establishment of grazed fields on the surrounding lowlands with the rapid spread of *Pteridium* and *Ulex*, suggesting the invasion of field boundaries. The appearance of introduced *Fagus* and *Castanea* (sweet chestnut) at the same horizon is seen as further evidence of colonisation of disturbed areas and is associated with archaeological evidence of la Tène agriculturalists, a Celtic culture known to be represented in Britain and Ireland by 300 BC. At this time rapidly expanding mires on the hillsides and valley floors are indicative of a deterioration of the climate. Brown (1977) regards this interpretation of the youngest deposits, without the benefit of reliable radiocarbon dates, as rather tentative, and subsequent work on Bodmin Moor (e.g. Jones *et al.*, 2000; Geary *et al.*, 2000) suggests a more complex human interaction with the landscape including phases of intensive land use.

Until recently our knowledge of the prehistoric vegetation of Cornwall depended disproportionately on the palynological evidence from Bodmin Moor. As this is a highland area, however, it is unlikely to tell us a great deal about the changes in the vegetation during the same period in the rest of Cornwall, particularly on the coasts and in sheltered valleys (Burton *et al.*, 1995). In addition, there has been relatively little evidence from Bodmin Moor or anywhere else in the county for the vegetational changes that have occurred from the Bronze Ages onwards when the human impact can be expected to have grown. Some further evidence has come from the analysis of buried soils on archaeological sites (e.g. Dimbleby, 1963; Bayley, 1975; Smith 1984b) but more recently the analysis of longer peat and sediment sequences (e.g. Scaife, 1984; 2006, James *et al.*, 1992; Burton *et al.*, 1995; French, 1996; Environment Agency, 1999; Jones *et al.*, 2000 and Forster *et al.*, 2011) have started to expand the picture.

Scaife (2006) revisiting Higher Moors on the Isles of Scilly, a site first analysed in 1984, has found evidence of a late Devensian open landscape dominated by *Poaceae* and *Cyperaceae* with later *Juniperus*, small *Betula* (*B. cf. nana*) and *Populus*. This is followed by a Holocene climax vegetation, as on Bodmin Moor, of oak/hazel/birch forest with some elm. The sequence continues in the earlier archive (Scaife, 1984) showing what appear to be Neolithic

clearances. These early clearances were recolonised but followed by extensive secondary woodland clearance that is associated with local archaeological evidence of the Early and Middle Bronze Age. Both clearance phases have evidence of arable farming in the form of cereal pollen. The subsequent clearance resulted in a permanent opening of the environment but, unusually, without any evidence of an increase in ericaceous pollen. Bronze Age clearance is also evident in the more recent Cornish palynological investigations. Dimbleby (1963) describes a Bronze Age landscape at Otterham, north Cornwall, initially dominated by an alder/oak forest with some birch, gradually giving way to an oak/hazel/birch woodland with increased *Poaceae* including some cereals, and a steady *Calluna* curve. Bayley (in Miles, 1975) also looking at Bronze Age buried soils, this time in the St.Austell area, describes a landscape dominated by grass and hazel with some oak and alder and some *Calluna* (but no other Ericaceae). Although anthropogenic 'weed' species were present there were no cereals.

Pollen sequences representing a longer timescale have enabled these Bronze Age clearances to be placed into context. A long peat sequence from Chyandour, near Penzance (James & Guttman 1992), although dominated by the alder carr succession on the mire surface indicates the replacement of an oak/birch woodland in the vicinity by hazel, and a large rise in grass and bracken. Hazel frequencies then fluctuate accompanied by a further rise in grass and sedge. The one radiocarbon sample from 0.5 m of the 2.37 m core is dated 1770 ± 40 cal. years BP appearing to place this sequence into an Iron Age to Romano-British transition. Burton and Chapman (1995) interpreted a non radiocarbon dated peat sequence from Crift Down near Lostwithiel as indicating pre-Neolithic alder/hazel/birch forest. This is followed by a large drop in tree pollen, especially alder and hazel, and an increase in grasses and anthropogenic 'weed' pollen interpreted as Bronze Age clearance and pastoral agriculture. A discontinuity, possibly caused by peat cutting, is followed by an extreme drop in tree pollen with a big rise in grass and sedge pollen, the appearance of cereals and a further rise in the anthropogenic herb pollen. This is attributed to medieval farmers and is followed by a rise in alder, willow and ferns with the disappearance of cereals, that they ascribe to either the Black Death, the Little Ice Age or both.

Another longer pollen archive, from De Lank mire near St. Breward on the northwest edge of Bodmin Moor, has provided a recent addition to the palynological evidence from this area (Jones *et al.*, 2000). This has been carbon dated showing a base from the end of the Early Bronze Age, 3444 ± 39 cal. years BP, and the top levels from the 'present'. The base of the core contains about 40% tree pollen, indicating a largely open environment with alder in the valley bottoms and small copses of oak and hazel on the slopes. Birch was also present at low levels. Most of the remaining land pollen (45 - 49%) is grass including occasional cereal grains. The tree pollen gradually decreases to about 15% of the total, accompanied by an increase in the anthropogenic pollen that suggests pastoral agriculture. There is no increase in cereals until just before a discontinuity when both the tree and the cereal pollen rise. The discontinuity is most probably the result of medieval peat digging and the recommencement of the record is dated as the 'modern' period with a vegetation community very similar to today. Unfortunately there is no date for the top of the pre-medieval sequence but the pollen and charcoal record appear to show continual habitation with fluctuating degrees of cereal cultivation and grazing. This is supported by the archaeological evidence and it is suggested that the population fluctuations may have been the result of a changing climate in an agriculturally marginal area.

Soils from Iron Age/Romano British houses at Penhale Round near Fraddon give us some more reliably dated information from the post Bronze Age period (Johnstone *et al.*, 1998). They indicate localised oak/hazel/alder copses with some birch, heathland with *Erica* spp. and ferns, and extensive grasslands, with cereals, charcoal and anthropogenic pollen confirming its habitation by farmers pursuing both pastoral and arable land use. A long peat sequence from Stuffle on the St. Neot River near Hawks Tor, Bodmin Moor has been analysed by Walker (in Austin *et al.*, 1989, pp.179 - 223). It appears to provide a continuous record of vegetational changes from the Romano-British period to the present although this is only partially confirmed by radiocarbon dating. The base of the core shows an open environment dominated by grasses with some anthropogenic pollen but no cereals. The low levels of *Calluna* and *Erica* spp. pollen suggest that there was little heathland. Scattered alder and birch stands may have been present but hazel appears to be the most widespread with 10% of the total land pollen. By the medieval period *Calluna*, grass and sedge pollen have

increased, cereals have appeared but the tree pollen, including hazel, has fallen. This is consistent with a rise of arable farming and a continuing but falling level of pastoralism. By ca. 600 BP (1350 AD) it appears that the area was dominated by rough grazing with a continued rise in *Calluna* and the disappearance of cereals. The gradual increase in the anthropogenic pollen and the reduction of *Calluna* towards the top of the sequence is thought to bring us back to the modern age of intensive rough grazing.

In summary, the most recent evidence provides a picture of fairly extensive Bronze Age clearance of oak/hazel/alder woodland in the lower lying areas of Cornwall, remaining steady through the Iron Ages and then further expanding through the historical period. There is a reduction in all the tree taxa although levels of hazel appear to be the last to fall and the first to recover where agricultural activity is reduced. There is evidence of cereal growing throughout the period, from the Neolithic onwards, but the balance between arable and pastoral farming varies considerably both in time and in space. In contrast to the higher ground of Bodmin Moor where heathland is a consistent part of the flora, the low lying areas show varying levels. It is frequently absent during the early clearance phase but forms an increasingly important part of the flora from the Iron Age onwards. *Calluna* is a constant in these heathlands but the levels of ferns and other Ericaceous species vary.

1.4.3 The environmental history of the Lizard Peninsula

Hopkins (1983) provides a useful overview of the vegetational history of the Lizard using the evidence available at that time. Following the work of Brown (1977) he suggests that the periglacial features on the Lizard probably date from the Late Devensian. He supports the view that the small juniper population still extant on the Lizard (Duncan Lyne, Natural England, NE, 28.05.04, pers. com.) may be a remnant of that period. Although Brown found no significant evidence for pine on Bodmin Moor Hopkins points out that Borlase (1758) and Usher (1879) report submerged pine forests off the Cornish coast and Clarke (1970) describes pine as being important in the lowland Holocene vegetation of Devon. Pine cannot therefore be ruled out as forming part of the forest flora of the peninsula at some stage. Hopkins reports Rackham's view that the sessile oak Merthyn Wood on the north

bank of the Helford river is a primary woodland modified by coppicing and Rose's identification of lichens suggesting ancient woods on the northern edge of the Meneage. Hopkins sees these observations as evidence for primary woodland on at least parts of the Lizard, possibly only inland on the deepest soils, but he suggests that gale force winds might have prevented this.

Hopkins sees the history of the heathlands as being more problematic. He describes Malloch (1971) as providing 'convincing evidence' that the cliff top, maritime heath is a climax vegetation caused by salt spray. He suggests, however, that there is insufficient evidence to decide whether the inland heaths are natural, following the drying out of raised bogs on the poorly draining plateau, or man made as suggested by Gimmingham (1972) and Moore (1975) when considering the heathlands and mires of northwest Europe. If the latter is the case then the clearance of woodland may well have been the initial stage that lead to heath development.

Smyth (1974) analysed a buried Bronze Age soil from Polcoverack containing 55% *Erica* pollen, 19% grass and 7% tree, mostly hazel and willow, and Christie (1960) identified Bronze Age heathland expansion at Perranzabuloe. Crabtree (in Hopkins, 1983, p.39) compares putative Bronze Age burial soil to contemporary heathland soil. The Bronze Age arboreal pollen, mostly hazel and alder with some oak, birch, elm and ash, is 36% of the total compared to 4.4% in the modern soil. Grass and sedge accounts for 41% of the Bronze Age pollen but only 30% in the modern soil. The difference is made up with heathland species, the modern soil having 30% *Calluna*, 14% *Erica vagans*, 2% *E. tetralix* (type) and 3.5% ferns compared to 19% *Calluna* and a trace of *E. vagans* and ferns in the Bronze Age soil. Cereal pollen, a trace, only appears in the modern soil and the anthropogenic species, *Plantago lanceolata* and *Taraxacum*, increase between the Bronze Age and the modern soil. The picture that emerges from this interesting but unpublished work is of an open Bronze Age environment with hazel scrub, and alder in the valleys and poorly drained areas of the plateau. There is no evidence for cereal cultivation at this site but strong evidence of grazing.

Smith (1984b) conducts a similar exercise by looking at two sites on the top of Goonhilly

Downs near Croft Pascoe. The Bronze Age buried soil contains 55% to 70% grass pollen with significant levels of hazel (checked by S.E.M.), *Calluna*, *Alnus* and *P. lanceolata*. There is no cereal or *E. vagans* pollen. An adjacent site dated to the 13th to 14th centuries AD shows an even more open environment with reduced hazel, *Calluna* replacing grass and a decrease in *P. lanceolata*. This he interprets as indicating reduced grazing. He also records some *E. vagans* and cereal pollen but suggests that it may be washed down from the soil above. The soil above the buried soil is judged as 'modern' and shows the appearance of both cereals and *E. vagans* but with grass and *P. lanceolata* increasing again at the expense of grass. He relates this environment to the 'Short Heath' of Coombe and Frost (1956) gradually reverting to the 'Tall Heath' and suggests that the heathlands were more intensively grazed in the Bronze Ages than subsequently.

In a review of later Bronze Age settlements in the southwest Johnson (1980) identifies many barrows from the period on the Lizard plateau, especially around Goonhilly Downs. He describes much evidence for gabbroic clay removal but probably not much settlement. He suggests that the principal areas of settlement were the farms of Kynance, Poldowrian and Polcoverack and notes that the cooler, wetter weather in the late Bronze Age and early Iron Age that caused abandonment of marginal sites on Bodmin Moor and Dartmoor may, also, have impacted on areas such as the Lizard peninsula.

Hopkins notes that there is good archaeological evidence for Iron Age habitation on the Lizard (e.g. Peacock, 1969b), particularly that associated with salt extraction, but less evidence of the Anglo-Saxon period. Rackham's interpretation of Domesday (Rackham, 2003) reports Devon and Cornwall as remarkable for their low level of woodland cover in 1086 (3.8% and 3.2%) and its distribution in the form of 'large numbers of very small woods' (p.118). This figure had increased by 1895 to 5.2% and 3.6%. He suggests that the area of heathland would also have been broadly similar to that of today. In the early 16th century Richard Carew, reported in Halliday (1953), described husbandry on the Lizard as being neglected for tin mining but that this had reduced by the late 16th century when incursions were made into the heathland for growing barley and other cereals. He, and others, have described the importance of turf cutting (turf and peat) for use as domestic fuel and tin smelting. The 'Turbaries' as this process was known, were an important source of Duchy

income in 1359 (Hopkins, 1983) and Hopkins (1980) describes the use of turf for hut building in the 14th and 15th centuries, possibly associated with charcoal burning in the drier months. He considers that almost all the surface soil horizons would have been removed during this period. Carew reports the use of peat in the 17th century and turf and ‘Furze’ (mainly gorse) continued to be cut for fuel into the 19th century (Hopkins 1983). Hopkins also finds evidence for 19th century cultivation of heathland, a process called ‘burn-beating’ which was abandoned after a few years so returning to heathland.

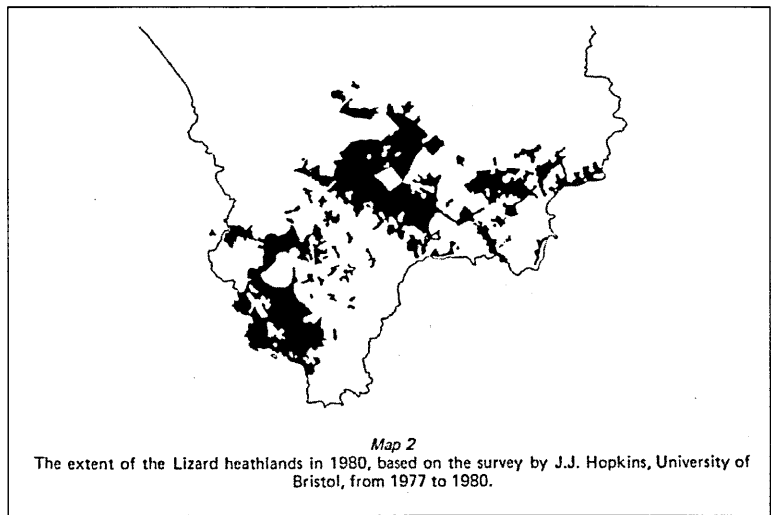
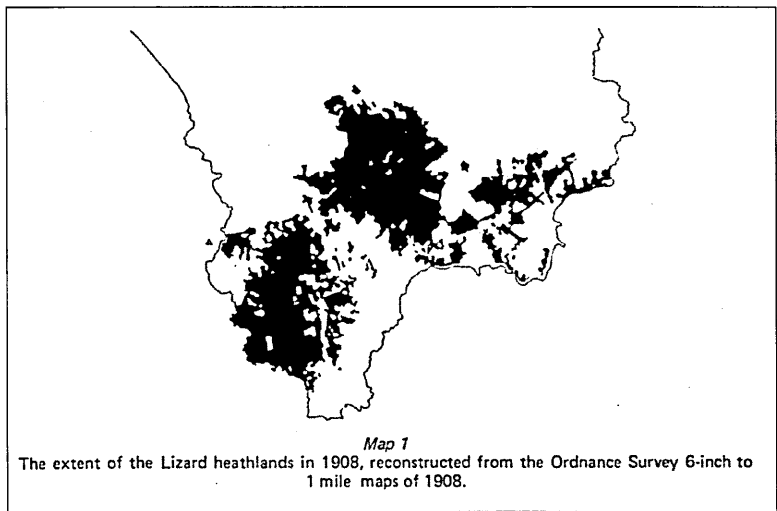


Figure 1.7 Map 1 based on OS data from 1908, and Map 2 from the work of Hopkins (1983) indicate the significant loss of heathland during the 20th century (from Turpin, 1982).

Maps from the 17th century onwards show the area of heathland as remaining fairly constant to the present day but in the 20th century, mostly between 1946 and 1973, about 520 Ha, one sixth of the total area, was lost to forestry, Predannack Airfield and Goonhilly Earth Station (Lake, 1976; Hopkins, 1983). Hopkins points out, however, that this is very little compared to other areas in the British Isles. Fig 1.7 shows the destruction and fragmentation of the Lizard heathlands between 1908 and 1980.

Recently two pollen archives from the western coast of the peninsula have been analysed. French (1996) has made a preliminary analysis of a 7.5 m core from the sediments under the extensive *Phragmites* reed bed at Gunwalloe, near Church Cove. Although without the benefit of radiocarbon dates he considers the base of the core to represent a pre-clearance phase, possibly Neolithic or Bronze Age as there is no sign of an elm decline. The tree pollen percentage is high indicating a surrounding woodland dominated by oak with hazel, alder, elm, *Ilex*, *Hedera*, *Lonicera*, ferns and dog's mercury. The pine, birch and lime pollen is considered to be from a distant source. Clearance becomes evident quite close to the base of the core involving first a modest drop in tree pollen with a corresponding slight rise in *Plantago lanceolata*, Poaceae and *Pteridium*. This is followed by a far more pronounced one with a much larger drop in tree pollen and a big rise in grass, sedge and *P. lanceolata*. Throughout most of this early phase cereal type pollen (>50µ) is present. The following 2 m of the core was not investigated and at the recommencement of counting very low tree pollen percentages suggest near total clearance. French (1996) suggests that this is consistent with a landscape inferred by the high levels of agricultural activity at the adjacent Winnianton estate indicated in Domesday (11th century). Cereal pollen is high, particularly towards the very top of the core. *Calluna* and other Ericaceae pollen are low but consistent throughout the core, as is *P. coronopus* pollen, suggesting that a steady cliff top maritime heath is being represented.

About 6 km further up the west coast of the peninsula at Porthleven, a 2.5 m peat core from behind the harbour wall has recently been investigated by Tinsley for the Cornwall Archaeological Unit (Environment Agency, 1999). This has been radiocarbon dated indicating a commencement in the Early to Middle Bronze Age (3900 cal. years BP). The top

of the core is modern (<200 years BP). The Bronze Age base of the core indicates a relatively dense woodland cover with >80% tree and shrub pollen, and <20% herbaceous pollen. The tree pollen is dominated by alder, with some oak and hazel and traces of elm, pine, birch, beech and ash. Between this point and a radiocarbon dated point of 2100 ± 60 cal. years BP the tree pollen drops to about 40% with a corresponding increase in herb pollen, mostly grass, up to 37%. The tree pollen then rises again to about 50%, mostly due to a rise in *Alnus* accompanied by a marked increase in *P. lanceolata* and other pollen indicative of disturbance. The tree and shrub pollen then drops to 12% and finally 4% with a large rise in grass to between 35% and 50% and a continued significant presence of disturbed ground species. Cereal pollen occurs throughout and there is a steady cliff top maritime heath community represented including *Calluna*, *Erica*, *Empetrum*, *Ulex*, *Scilla*, *P. coronopus* and *P. maritima*.

These two cores both indicate an initial high level of tree pollen suggesting a relatively dense woodland cover in their coastal valley sites. This is followed by clearance phases that finally result in the near treeless habitat associated with the peninsula today. This is in contrast to the Lizard plateau at Goonhilly and Polcoverack (Smith, 1984b; Smythe, 1974) and other inland sites (e.g. Bayley, 1975; Johnstone et al., 1998). Here a relatively open environment is evidenced from Bronze Age deposits with tree pollen as low as 7% in one case. The two Lizard cores from the west coast indicate that cereal growing was occurring throughout the time period represented, even before major clearance, and both sites appear to show consistent cliff top heath communities present in their vicinity. The status of *Erica vagans* is visited at two sites, Smith (1984b) finding traces of *E. vagans* pollen only in the medieval soils while Crabtree (in Hopkins, 1983) found traces of the pollen in Bronze Age buried soil.

Straker (2011) in her review of the palaeoenvironmental literature of West Cornwall for the HEATH project looks at evidence from a range of proxies including many of those cited above. The difficulty with finding suitable, undisturbed sites and the lack of radiocarbon dating for many of the studies that have been conducted limits the information available. She does, however, make three observations about the Lizard and West Penwith palaeoenvironments with some confidence. Coastal valley wetlands have been identified

supporting a rich tree and ground flora, principally of alder fen carr with some willow or birch. Oak/hazel woodland was frequent on the drier areas up the valleys and on the plateau tops. By analogy with elsewhere in Cornwall she suggests that this will have developed by ca. 10000 years BP and persisted for longer on West Penwith than the Lizard. She estimates that clearance on the Lizard occurred during or before the Bronze Age but not until 'the last millennium BC' in West Penwith (p.71). Heathland appeared to be a characteristic of the cleared areas of the Lizard from the Bronze Age but there is little evidence for this on West Penwith. She identifies evidence for late prehistoric pasture on the Lizard but this is much less strong for arable farming. Finally she reviews the limited evidence for the historic period suggesting that the landscape became increasingly open.

1.5 The archaeological record for Cornwall

Understanding the human impact on the environment, particularly in relation to heathland development, is one of the principal research aims of this thesis. In order to ensure that all the available evidence is used in elucidating this, a review of the current archaeological literature of the region has been conducted. It involves both a consideration of excavations and prehistoric artefacts assembled by archaeologists working in Cornwall and the southwest, and the reconstructions of prehistoric economies that these, combined with other evidence, have produced. The locations of the sites in western Cornwall mentioned here are shown in Appendix II.

1.5.1 The Mesolithic

Some evidence of sporadic Palaeolithic human activity in Cornwall has been described (e.g. Roe, 1968; Collcut, 1986) but the Mesolithic period is the first with convincing evidence of sustained human occupation. This is supported by radiocarbon dates from excavations on the Lizard, at Windmill Farm of 6210 ± 150 uncal. (7088 ± 338 cal. Oxcal.) years BP on charcoal and Poldowrian of 6500 ± 110 uncal. (7382 ± 205 cal.) years BP on hazelnuts (Smith & Harris, 1982; Smith, 1984b).

The review of the Mesolithic in Cornwall by Berridge and Roberts (1986) provides a useful synopsis of the state of our knowledge up to that time. They explain that the acid soils of Cornwall have not preserved organic artefacts but that there are many well documented lithic artefacts from the period. Flint and chert from beach pebbles are an important source material (Naylor and Shannon, 1982) but there is also evidence of the importation of greensand chert from Devon (Berridge, 1985). One of the most commonly found Mesolithic tools throughout Europe are microliths, assumed to be the tips and side armatures of arrows. Jacobi (1979) has used microlith assemblages to assign a Mesolithic age to several sites in Cornwall. The much larger scrapers are frequent finds in Cornwall, used for working animal hides, wood, antler and other materials (e.g. Dumont, 1983). These had traditionally been assumed to be of Mesolithic origin but there has been speculation (Berridge & Roberts, 1986) that some may be of Neolithic age as the differences in these tools between the two periods is not clear cut. The other relatively abundant Mesolithic finds in Cornwall are 'miscellaneous retouched pieces' without any clear function. Axes and adzes, two very similar tools, are found at some Cornish localities, and choppers and picks made from flint and chert beach pebbles are found along the coast.

The frequency of these finds, particularly on the Lizard (Smith & Harris, 1982) establish the presence of significant numbers of Mesolithic people in Cornwall whose economy can be deduced from more general investigations of Mesolithic activities in the British Isles. Orme (1982, ch.4) shows that contemporary hunter-gatherer groups move around a territory following the seasonal availability of their food sources. Clarke (1972) proposed a model of Mesolithic activity in northeast Yorkshire in which lowland areas were exploited during autumn, winter and spring, and upland areas in summer. Jacobi (1979) conducted a similar exercise for the Mesolithic period in the southwest. His model suggests that estuarine areas were exploited in late spring and early summer for their considerable mollusc, fish and bird populations with the uplands favoured in the summer for their grazing deer populations. The rocky coastlines were used during autumn, winter and early spring for molluscs, fish, birds and seals. Ungulate hunting in the woodlands would also have augmented the winter diet.

Although a useful model Berridge and Roberts (1986) point out that in Cornwall these three ecological zones are very close to each other such that factors such as seasonal plant availability and the presence of lithic raw materials for the manufacture of tools may have also played an important role in choosing between areas of similar fauna potential.

These models of a semi-nomadic existence of Mesolithic people throw up the question of the function of the various sites in Cornwall that have been excavated and described. On the Lizard, the subject of this study, Poldowrian is located on a cliff top overlooking the coast and is interpreted by Smith and Harris (1982) as a 'base camp' occupied, at least, during the autumn and winter months of the late Mesolithic. Smith suggested a similar function for the Windmill Farm site on Predannack Moor (1984b). The Croft Pascoe site on Goonhilly Downs, however, with a smaller artefact assemblage dominated by microliths is thought by Smith (1984a) to be a temporary hunting camp. Smith's 'Lizard Project', a Landscape Survey conducted between 1978 and 1983 and involving an extensive surface collection over 265 Ha, was published in 1987. Extrapolations from 700 minor and 600 larger Mesolithic occurrences support this earlier view of his that the main economy was on the coast with smaller foraging sites inland.

In summary, the current state of our knowledge indicates that there was a significant Mesolithic population in Cornwall, and the Lizard peninsula clearly falls into this category. They were almost certainly semi-nomadic hunter-gatherers exploiting both the highly productive estuaries and rocky coasts and the ungulate populations of the wooded interiors. It is generally assumed that the Mesolithic people had little impact on the vegetation although there is evidence (e.g. Simmons, 1969; Mellars, 1975, 1976) that woodland clearances were created to manage ungulate species, particularly grazers, and to encourage hazel for their nut harvest.

1.5.2 The Neolithic

The environment of the southwest during the Neolithic period is best described from the relatively extensive evidence available from Dartmoor, (e.g. Fyfe *et al*, 2008; Staines, 1979).

Neolithic groups are implicated in the initial clearance of upland areas at about 5500 cal. years BP associated with the first establishment of heathland possibly linked to leaching and acidification. The oak dominated woodland on the lower land remains intact until the Neolithic/Early Bronze age transition when there is widespread destruction of the forests. In the Shovel Hill area of Dartmoor (Fyfe *et al*, 2008) hazel scrub returns to the uplands suggesting reduced usage in this area in the Bronze Age. Walker and Austin (1985) have identified a similar sequence at Redhill marsh on the south side of Bodmin Moor. They attribute the stability of the open grass/sedge/heather/hazel environment following the clearance phase as most likely to have resulted from over-grazing and the poaching of the ground by cattle.

Similar evidence for early clearance comes from turf buried below a probable Bronze Age cairn near Altarnum on the north east edge of Bodmin Moor (Brisbane & Clews, 1979). Here oak woodland with some birch and elm, described as 'wildwood' after Rackham (2003), had been destroyed while hazel and alder continued to flourish. This is interpreted as the pre Bronze Age selective felling of oak followed by the establishment of patchy grassland with no evidence of cultivation. When considered alongside other pollen data for the region (e.g. Walker & Austin, 1985) this is considered to provide evidence of Mesolithic intervention opening up areas of light upland forest on the slopes of higher ground enabling deer, wild pigs and aurochs to thrive. Such behaviour is well documented in northwest Europe (e.g. Mellars, 1975). After 5000 years BP and with the arrival of the Neolithic, however, extensive clearance of woodland occurs with the establishment of significant grassland swards (Mercer, 1970). Coastal areas of Cornwall with thin soils and high winds would have also been lightly wooded and mollusc and pollen evidence (e.g. Spencer, 1975; Smith & Harris, 1982) indicate that they too were the subject of anthropogenic clearance in both the Mesolithic and early Neolithic. Despite this apparent overlapping of types of woodland exploitation there is no convincing archaeological evidence for Mesolithic influence on succeeding Neolithic cultures (e.g. Whittle, 1977).

The study of the lithic artefacts of the Cornish Neolithic has to take into account several difficulties (Mercer, 1986). The first of these is the problem of establishing rock sources. It

has been speculated that these may now be submerged. Also of importance is the very small sample size of axes and other stone artefacts. Mercer estimates that the Neolithic artefacts that have been collected represent only about 0.0025% of the total output. Any conclusions from type and distribution must therefore be very limited.

Some features of distribution are significant even within such a small sample, particularly the early Neolithic lack of grouping of axes. This suggests small scale sources with few surviving samples (Cummins, 1974, 1979; Smith, 1979). Although there is no evidence that these quarry products were transported east, Devon beerflint and Dorset Portland chert have been found as far west as Penwith. This distribution pattern appears to change from about 4500 years BP when it becomes more complex with Cornish axes appearing to have been moved by sea to Poole harbour in Dorset, Clacton in Essex and possibly Flamborough Head in Yorkshire from where they were distributed inland (Cummins, 1974). Mercer (1970) speculates that these axes arose from an industry centred on Mounts Bay. Similar earlier centres of manufacture for further distribution have been provisionally identified from the St. Ives area (Zennor to Camborne) and Balstone Down near Callington with their products appearing at sites in Dorset such as Hembury, Maiden Castle and Hambeldon Hill and as far east as Wiltshire. In this latter case they appear to have been transported overland.

A similar pattern of manufacture and distribution is evident within the Neolithic pottery industries. Peacock (1969) has identified a pottery manufacturing centre at St. Keverne on the Lizard peninsula using the local gabbro as grits for tempering its fabric. These pots have been found in large numbers at Carn Brea and Helman Tor in Cornwall, but also at Hembury and Maiden Castle in Dorset, and Windmill Hill in Wiltshire. It appears that this industry faltered at about the same time as the coastal distribution of stone implements was established.

One of the findings of Smith's 'Lizard Project' (1987) was that the Neolithic economy differed markedly from the Mesolithic. It spread throughout the landscape although biased towards the coasts that had been the focus of the Mesolithic economy. This observation is based upon 600 minor and 1,200 larger Neolithic 'occurrences' in his extensive surface

collection. Tilley (1995) argues that throughout the Neolithic and the Bronze Age, rock outcrops became increasingly important as symbolic resources, with restricted access and the development of strategies for their appropriation and control. In Mercer's review (1986) he describes in some detail the significant and extensive excavations of Carn Brea, 20 km north of the Lizard, and Helman Tor on the edge of Bodmin Moor. Both sites had boulder-built fortifications on pre-dug platforms and a wealth of artefacts, some mentioned above. The very large numbers of arrowheads collected at Carn Brea during successive excavations, over 1,000 in total, along with evidence of burning, are interpreted as a terminal attack on the site. These observations would support Tilley's view of the high importance placed on these prominent inland sites.

Also very important indicators of Neolithic culture are the funerary monuments found throughout the region. Mercer puts them into three categories; chambered tombs that have a particular concentration on the north coast of Penwith, oval and long barrows and 'Entrance Graves' whose centre of distribution appears to be on the Isles of Scilly. There is much evidence to link these structures to burials but further interpretation of their significance is speculative. To these enigmatic Neolithic monuments has to be added the stone circles. These are more varied in Cornwall than in almost any other region of the British Isles (Mercer, 1986) and indicate a sharp divergence from similar monuments on the European mainland. Although usually considered to have a ceremonial function their true purpose has, again, to remain speculative. The large numbers of these monuments, however, is possibly indicative of the increased use of the whole of the landscape during the Neolithic, as identified by Smith (1987) on the Lizard, and of the extent and strength of the Neolithic economy in the region. Mercer (1970) notes that the divergence of the designs of these monuments from elsewhere in Britain may indicate an increasing parochialism and seclusion into which the region was slipping. This may be related to the relatively steep and unpromising inland terrain for the purposes of 'landnam' (land taking). But the continued demand for the sea borne trade in Cornish rock (and the later importance of tin and copper) continued to sustain and even feed expansion in human settlement from ca. 4500 years BP until well into the Bronze Age.

1.5.3 The Bronze Age

The concept of the 'Bronze Age' has been continuously modified as dates and data resulting from more advanced excavation and research methods have accumulated (Christie, 1986). It is now seen as much more complex than previously described, overlapping into both the Neolithic and the Iron Age. A chronology based on the work of Pearce and Burgess (in Christie, 1986, p.82) indicates that the first copper axes appeared in the Final Neolithic at ca. 4500 years BP and the Bronze Age industries continued until ca. 2600 years BP, a span of almost 2,000 years. Within this period there are distinct cultural changes between the Early, Middle and Late Bronze Ages (e.g. Jones, 2008).

The Bronze Age environment of Cornwall, as evidenced by palaeoecological studies, is discussed here in section 1.4.2. To summarise Dimbleby (1963), James and Guttman (1992), Burton and Charman (1995), Jones (1998) and Jones and Tinsley (2000) have analysed the palynological evidence from palaeosols and longer cores encompassing the Bronze Age period. The picture produced is of relatively open woodland usually dominated by oak and alder with some birch at the start of the period. This gives way to an apparently much more open landscape with low tree pollen percentages dominated by hazel with some oak and high Poaceae, anthropogenic 'weed' species and sometimes *Calluna*. This sequence and evidence from elsewhere in Britain (e.g. Bennett, 1983) indicates warmer and drier conditions during the Early Bronze Age becoming wetter from ca. 3500 years BP.

An important area of investigation into the Bronze Age is the identification and excavation of settlements. Johnson (1980) identified 43 sites in Cornwall with dateable finds or morphological characteristics that placed them in the Bronze Age. Three significant finds have been made on the Lizard Peninsula, at Poldowrian (Smith & Harris, 1982, pp.23-66), Kynance Gate (Thomas, 1960, 1969) and Polcoverak (Smith, 1987). Smith's excavations on Goonhilly Downs (1984) suggest that the high concentration of burial mounds there indicates a high settlement status during the Middle and Late Bronze Age. Christie (1986) speculates that this may have been linked to increased exploitation for metals resulting from political changes elsewhere in the region.

A tighter focus on the significance of these excavations can be made by a consideration of two more recent lowland Later Bronze Age settlement excavations. These are at Trethellan Farm near Newquay (Nowakowski, 1991) and at Callestick near Perranporth (Jones & Taylor, 2004, Jones, 2008). The sites were occupied for extended periods, Trethellan from ca. 3200 to 2975 cal. years BP and Callestick from ca. 3100 to 2700 cal. years BP. Trethellan is described as a farming settlement of some size with abundant ceramics and diverse buildings pointing to small scale mixed farming with evidence of trade and metal working. It is estimated that it supported up to 30 people. One of its significant features is its apparent systematic, abrupt abandonment, almost certainly prompted by cultural and social rather than environmental factors. 900 years after its abandonment it became an Iron Age cemetery. The Callestick excavations indicate the importance of ritual and of objects, in particular ceramics, beyond their purely practical value. Of particular significance is the finding of very elaborate settlement abandonment processes involving quartz stones and artefacts. Jones (2008) suggests that many of these features have been drawn from the Earlier Bronze Age when they were associated with Barrow construction on the then largely vacated highland sites. The adoption of these processes in the Later Bronze Ages suggests continuity within a period of profound change. The ritual role of artefacts in addition to their practical roles would place added significance to areas such as Cornwall, and particularly the Lizard peninsula where both metalliferous outcrops and gabbroic clay could be exploited.

Timberlake (1992) in a review of prehistoric copper mining throughout Britain and Ireland, suggests that the location of copper and tin ores would have conferred some economic importance on a region, particularly when located within a fertile area. Although no direct evidence of prehistoric metal ore mining has been found in Cornwall it is most likely that coastal copper and tin lode outcrops would have been exposed by erosion and so visible and easy to work. Further erosion and rising sea levels will have obscured these. A find of a stone hammer with a probable mining function in Penwith (Cornwall Archaeological Unit) is currently the only indirect evidence for Bronze Age mining in the region.

Although the importance of metal ores in Bronze Age Cornwall can only be inferred there is substantial evidence for both the production and importance of Cornish ceramics. Harrad (2004) has analysed clay from prehistoric pottery and at locations throughout Cornwall. This has demonstrated that prehistoric Cornish gabbroic pottery originated in a small area of the Lizard peninsula. Different versions of the clay, for example loessic/gabbroic, serpentinitic/gabbroic and granitic/gabbroic suggest pottery production in “...several small scale cottage industries which may have operated on a seasonal, part-time basis” (Harrad, 2004, p.271). It is suggested that these formed only a part of a wide range of activities on the Lizard. Typology has allowed relative dating showing that some of the different clay types were used at different times through the Bronze Age and into the Iron Age whilst other different clay types were used during the same period. Also of significance is the finding of gabbroic based clays elsewhere in Cornwall pointing to internal movement of the Lizard gabbroic clay within the region.

The recent studies of Jones (2008), Harrad (2004) and Nowakowski (1991) can be set into context within the picture of the Bronze Age in Cornwall provided by Christie in her 1986 review. She describes an extended Bronze Age during which it appears that climatic changes, possibly linked to anthropogenic land changes, caused clearly identifiable movements of people from high moors to lower lying areas. Accompanying these shifts were profound cultural changes, most notably a decline in barrow building. However, as Jones (2008) points out, there are still clear signs of cultural continuity, particularly in ritualistic behaviour, linking the Middle and Late Bronze Age with the Early Bronze Age.

The importance of the links between Cornwall and other Atlantic seaboard regions appears to grow during the Bronze Age. By ca. 4000 years BP Christie (1986) suggests that Cornwall was more in touch with Ireland and Brittany than the rest of England. Rowlands (1980) describes a discrete ‘Atlantic regional economic zone’ from ca. 3000 years BP to the start of the Iron Age at ca. 2600 years BP.

The extended period of the Bronze Age and the highly significant changes within it will be an important area of focus in the current study.

1.5.4 The Iron Age and Roman Period

The transition from the Late Bronze Age to the Iron Age appears to be a slow process that is still not well understood (Christie, 1986). This is particularly true of Cornwall where iron objects, in particular, very rarely survive the acid soils. In Britain as a whole, however, the transition from bronze to iron tools is seen to occur throughout the 7th century BC so a date of ca. 2600 years BP is usually accepted as the start of the Cornish Iron Age (Quinnell, 1986). Our understanding of the early part of this period, 2600–2400 years BP, is supported by limited evidence, possibly due to population dislocation resulting from linked climatic and edaphic factors. The move away from higher regions, in particular Dartmoor and Bodmin Moor, to lower areas where settlement and field patterns are less well preserved, may play a part in this apparent reduction in population, however.

The characteristic features that are used to mark the start of the Cornish Iron Age are pottery changes and the appearance of hill forts (Quinnell, 1986). The early part of the period can be identified from an undecorated form of pottery that appears to be copies of Late Bronze Age metal vessels (Pearce, 1983). Pottery of this type has been found at many sites in Cornwall (Dudley, 1956, 1958, 1962) notably Kynance Gate on the Lizard (Thomas, 1960). This early period, from ca. 2600 to 2400 years BP, is characterised by rapid ceramic change that stabilises with the Later Iron Age from ca. 2400 years BP (Quinnell, 1986). Peacock (1968, 1969a, 1969b) has demonstrated that almost all the pottery from this period contains minerals from the gabbroic rocks of St. Keverne on the Lizard peninsula. This is supported and extended by Harrad (2004) who has demonstrated this from the gabbroic pottery both for the Bronze Age and extending into the Iron Age in Cornwall. The Later Iron Age pottery tends to be smaller, decorated and better made than that from the Late Bronze Age. Quinnell (1986) suggests that it was this centralisation of production that led to the stability of ceramic style and type but since Harrad (2004) has shown that this centralisation extends back into the Bronze Age other reasons for the instability of the ceramic types of the Earlier Iron Age need to be considered. In addition to evidence supporting the importance of the gabbroic rocks of the Lizard, Peacock (1969a) has demonstrated that salt was mined at Trebarveth, St. Keverne during the 3rd and 4th centuries AD (1750 to 1550 years BP).

The most characteristic settlements of the period are the courtyard houses of West Penwith, of which the examples at Chysauster, Porthmeor and Carn Euny are the best preserved. Further east in the county, however, the appearance of oval houses, probably with ridged roofs, is an indication of gradual change linked to Roman influence. Evidence for field systems associated with these settlements is often present. Guthrie (1969) has demonstrated it at Goldherring and Johnson and Rose (1982) have demonstrated the presence of similar field systems around Iron Age settlements throughout Cornwall using aerial photographs. There is also good evidence of arable farming. Guthrie (1969) has recorded the presence of *Hordeum* spp. (barley), *Avena* spp., (oats) and *Secale cereale* (rye) at Goldherring. Miles et al. (1977) have reported *Triticum dicoccum* (emmer), *T. spelta* (spelt) and *Avena* sp. at Kilbury.

Hillforts, although first identified from the Late Bronze Age most particularly in Wales (Harding, 1976), are more usually associated with the Iron Age. Many Cornish sites may be designated as hillforts, in particular the 'tor enclosures' of the granite moors such as Trencrom near St. Ives (Silvester, 1979) and the cliff castle at Trevelgue near Polzeath, where pottery findings suggest continuous occupation from the Late Bronze Age and through the Iron Age (Quinnell, 1986). There is evidence of influence from Brittany or northern France in the cliff castles of this period, as well as burial sites and fogous, probably resulting from the tin trade (e.g. Hawkes, 1984).

The same geography that encouraged contact across the English Channel also appears to some extent to have isolated Cornwall from the rest of Britain. Three Roman forts have been identified in the county. The first to be described is at Nanstallon just west of Bodmin on the river Camel occupied from ca. 55 AD until 80 AD (Fox & Ravenhill, 1972). A more recent find has been at Calstock on the river Tamar, just below Gunnislake, currently being investigated by a team from the University of Exeter. Despite these clear signs of Roman involvement in the region there is little evidence of Roman influence in the life of the Cornish Dumnonii people, with no baths, mosaics or theatres (Quinnell, 1986). Although pottery (amphorae) from as far afield as Spain, found at Castle Gotha (Saunders & Harris, 1982), suggest the import of wine and oil, it is not possible to say if this resulted from

Roman influence or the proximity of mainland Europe.

Tin mining continued to be an important source of wealth and trade through the Iron Age and Roman period, but there is evidence that even this link with the rest of Britain assumed reduced importance during the 1st and 2nd centuries AD when Iberian mines were supplying the needs of the Roman Empire. The Cornish Dumnonii's settlements and life style remained socially stable with little disruption into the 5th century AD (Quinnell, 1986) while elsewhere in Britain the development of the monetary economy and increasing differentials in wealth apparently created difficulties resulting in social instability and dislocation. This was at a time when the population of Britain as a whole is considered to have been expanding rapidly (Salway, 1981). Cornwall thus appears from this picture as a culturally backward but socially stable Iron Age outpost of the Roman Empire.

1.6 Holocene heathland development in northwest Europe

One of the aims of this study is to elucidate the age and origins of the heathland of the Lizard plateau. To inform this analysis the contributory factors to the Holocene development of lowland heathland throughout northwest Europe are investigated here. These can be defined as areas below 250 m dominated by dwarf shrubs of the Ericaceae family. The regions in which lowland heathland develop are shown in Figure 1.8 below.

In his comprehensive overview of the ecology of heathland in northwest Europe Gimmingham (1972) provides an analysis of the evidence then available. He points out that heathlands occupy a climatic zone characterised by a 'moist temperate climate with mild winters' (p.11) with no extremes and high, evenly distributed rainfall. He also describes heathland flora as 'essentially acidophilous' (p.13) and thus usually associated with oligotrophic, more or less podsolized soils. Podsolization, he points out, might have been partially the result rather than the cause of heathland establishment causing the degeneration of former brown-earth soils.

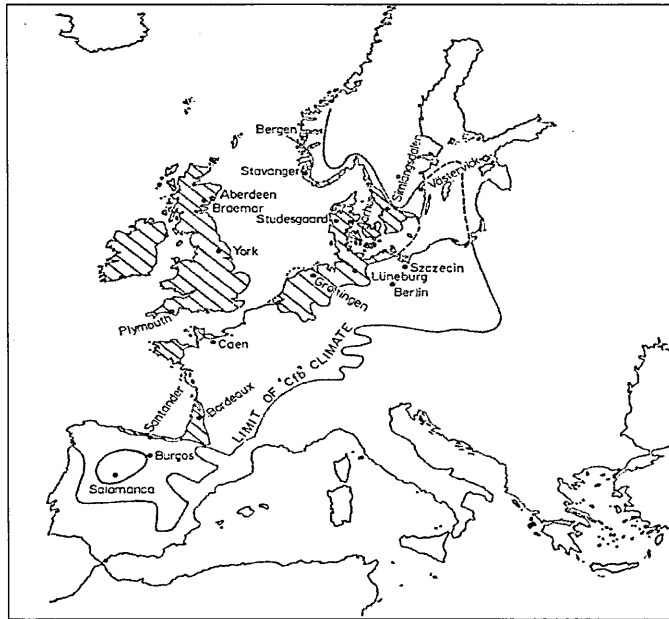


Figure 1.8 Western Europe showing (hatched) the main areas of lowland heath. The 'Cfb' climatic zone, moist temperate with mild winters, is also indicated (from Gimmingham 1972).

Climatic and edaphic factors are a necessary condition for heathland development but the same environment also supports northwest European deciduous and coniferous forest types. Gimmingham (1972) suggests that they therefore cannot be regarded as a 'regional vegetational complex' (p.16). The invasion of heathlands by trees is commonplace suggesting that to maintain heathlands, environmental factors that prevent the establishment of trees must be present. Many workers have pointed out that these may be natural factors such as altitude or coastal exposure (e.g. Tansley, 1939; Mc Vean & Ratcliffe, 1962; Mallock, 1972). Faegri (1940) and Bøcher (1943) concluded that this is the case in some southwest Norwegian sites where the current environment is not conducive to tree growth. More recent work from northern Norway, however, (Moe, 2003) clearly links deforestation and subsequent heathland development with anthropogenic factors. Moe (2003) also cites a series of studies (e.g. Selvick, 1985; Kaland, 1986) that link deforestation, heathland development and heathland persistence with anthropogenic activity. Myhre and Myhre (1972) postulated that the heathland economy of grazing and burning most probably spread from the southwest region of Norway, along the coast to the northern region.

A more complex picture of heathland development emerges from studies of northern Scotland and the Scottish Isles. Durno (1958) citing evidence from pollen analysis in eastern Sutherland and Caithness suggests that the decrease in tree pollen and sustained increases in Ericaceae pollen occurred before any significant interference by humans. This view is supported by Bunting (1996) who finds the first signs of heathland development at Loch of Torness, Orkney at ca. 7000 years BP with no evidence of an anthropogenic influence. Even earlier onsets of peatland and heathland development, from up to 9000 years BP, have been identified in northern Scotland by Peglar (1979) and Gear (1989), and in the Western Isles by Birks and Madsen (1979). Later increases in heath vegetation identified in Caithness (Peglar, 1979) and Shetland (Bennett *et al.*, 1992, 1993) at ca. 3000 years BP coincide both with possible climate change and evidence of intensifying human activity.

In more southerly regions of the British Isles the evidence is less ambiguous. One of the earliest examples of the series of changes associated with the production of open heathland can be found in the analysis of the vegetational changes at Hockham Mere in Norfolk (e.g. Godwin, 1944; Bennett, 1983) spanning a period from late Devensian (ca. 12600 years BP) to historical times. The more recent study (Bennett, 1983) shows an open *Betula* woodland followed by near complete woodland cover during the Boreal and Atlantic periods (ca. 9500 to 4500 years BP) with very little non-tree pollen. At the time of the elm decline, ca. 4500 years BP and usually associated with the start of the Neolithic, non-tree pollen rises sharply with the principal contribution coming from Poaceae, Ericaceae, *Plantago* spp. Cyperaceae and Asteraceae. Godwin (1975) points out that archaeological evidence indicates that this region was at least as densely populated as anywhere in Britain during Neolithic times with the flint mines of Grimes Graves being only about 16 km from the site (p.467). The association of anthropogenic activities, evidenced by charcoal fragments and weed and cereal pollen, with steep rises in non-tree pollen and subsequent falls in tree pollen, have now been established at many sites throughout the British Isles, for example by Conway (1947) in Yorkshire, Pennington (1965) in North Lancashire and Haskins (1978) in Dorset. Permanent clearance often follows a period of 'small temporary clearances', however, as shown by Turner (1964) at Tregaron Bog, Cardiganshire.

The extent to which typical heathland flora, in particular Ericaceae, develop in the cleared areas varies and appears to be dependent on both the soil characteristics and the subsequent patterns of land use. Dimbleby (1962, 1965) found that buried Bronze Age soils showed early signs of podsolization in areas now highly podsolized. He concluded that forest 'degeneration' and subsequent heathland growth were due to the disturbance of the ecological equilibrium resulting from human activities. In summary, then, most of the evidence supports the anthropogenic origins of heathland development following forest clearance and the introduction of grazing and cultivation, this 'clear[ing] the way for the expansion of heath' (Durno, 1958) by inhibiting forest regeneration and inducing or accelerating edaphic changes. As the climate becomes more oceanic, however, as occurs in the more northerly areas of northwest Europe, climate may become the dominant factor.

A general agreement with this supposition comes from the recent work of Groves *et al.* (2012) whose review of the origins of lowland heathland in southern England is supported by new palaeoecological evidence from valley peat sites in Hampshire and West Sussex. They point out the difficulties of establishing the origins and dynamics of this type of habitat due to the paucity of suitable sites and the frequency with which those sites that have been investigated contain hiatuses, probably as a result of peat digging. Also problematic is the regular occurrence of members of the Ericaceae, including *Calluna*, in non-heathland settings and on mire surfaces from which cores have been investigated (e.g. Grant *et al.*, 2009, Bunting, 2003). Of particular significance, however, is the unusually late survival of *Pinus* at levels above 20% of the total land pollen (TLP) at the Conford, Hampshire site where it persists until 6050 cal. years BP. This they ascribe to frequent fires in which *Pinus* recovers more quickly than deciduous trees, and edaphic factors, in particular low soil fertility and frequent water-logging.

None of the other 13 lowland heathland sites reviewed show such a late fall of *Pinus* below the 20% of TLP threshold proposed by Bennett (1984) as indicating the local presence of pine. At Gatcombe in the Isle of Wight Scaife (1982) dated the *Pinus* fall to 7300 cal. years BP and at the remaining sites it was considerably earlier. Using *Calluna* values of >2% of TLP as an indicator of extra-local heathland pollen input Groves *et al.* (2012) suggest that

heathland existed from the Late Neolithic (ca. 4300 cal years BP) at both the Conford and the Hurston Warren (West Sussex) sites. Expansion of the heathland at both sites occurred in the Late Bronze Age (ca. 3000 cal years BP) with further expansion during the Iron Age from ca. 2600 cal. years BP associated with increased charcoal values. The general conclusion from this study is that the lowland heaths of southern England were created by human manipulation, with burning being an important constituent in their establishment and maintenance. They also suggest that extant areas of heathland will have considerable variation in the history of their development both in the timing of their appearance and in their continuity.

During the historical period, palynology and archaeology merge with documentary sources in the provision of evidence for the reconstruction of past environments. By the end of the Middle Ages (ca. 1500 AD) written sources become the most important, both because their quantity increases, but also because vegetational changes become too rapid to be reliably detected by pollen diagrams (Webb, 1986, p.36). The Domesday Survey (1086) provides evidence of extensive forest clearance in England, particularly in the Breckland region. Subsequent documentary evidence indicates rapid forest clearance, for example in the Pennine area (Conway, 1947) associated with agricultural expansion and charcoal production for iron smelting. The process of woodland clearance was virtually complete by the end of the 17th century with much of the open land produced being used for grazing and arable farming. On poorer acid soils where cultivation was difficult, heath communities established and were maintained by low density grazing, principally cattle and sheep. Regular burning encouraged new *Calluna* growth for forage (Gimmingham, 1972, pp.27-28). In some areas fuel gathering involving gorse (furze), scrub and bracken also contributed to the vegetational structure of the heathlands and the reduction of nutrients in the soil. The cutting of turf, principally for fuel, on the Lizard Peninsula identified by Hopkins (1980) has already been referred to in section 1.4.3 above. This would also have had the effect of reducing the nutrient status of the soils so maintaining the heathland communities.

With the increasing of agricultural efficiency during the 20th century the grazing of heathland became less economically viable and much heathland reverted to scrub or was lost to

cultivation, residential development and afforestation. These losses have been particularly pronounced in Scandinavia and the Benelux regions of Europe (Gimingham 1972, pp.28-32). Webb and Haskins (1980) have used cartographical evidence to estimate a reduction of heathland in Dorset and Hampshire since the mid 18th century of more than 80%. Armstrong (1973) finds a similar loss of heathland over this period in Suffolk. Hopkins (1983), using, amongst others, documentary evidence held in Exeter Cathedral library going as far back as the 10th century, has found few changes in the extent of heathland on the Lizard peninsula up until the 20th century when significant losses are recorded (see Fig. 1.6).

1.7 The palaeoclimates of the Holocene

Climatic variations have both direct and indirect impacts on palaeoecology. The flora responds directly to changes in mean seasonal temperatures, temperature ranges and precipitation. Climate induced environmental changes in turn impact on human populations. The importance of climate change to human migrations and socioeconomic change is an under researched area, possibly as a result of its multidisciplinary nature (Caseldine & Turney, 2010). That there are links is not disputed. Turney and Brown (2007) link sea-level rise in the early Holocene with the spread of Neolithic farming inland throughout Europe. They argue that coastal, lakeside and river floodplain locations would have been favoured for agriculture but were also the most vulnerable to the catastrophic rise in sea-level when the Laurentide Ice Sheet collapsed between 8740-8160 cal. years BP. This resulted in the displacement of the Neolithic population whose agricultural activities expanded to inland areas. The much later arrival of agriculture in northwest Europe may have been associated with the difficulties of crossing sea barriers and the success of the indigenous Mesolithic culture. Bonsall *et al.* (2002) also considered the causes for the delayed Neolithic transition in northwest Europe. They note the evidence for the synchronous nature of its arrival and also that it coincides with a drier, more continental climate in the region, particularly well evidenced in the stratigraphy of peat bogs in western Scotland ca. 6100 years BP. They point out the difficulties the early farmers would have had with water-logging and suggest that the drier climate, especially in winter, was crucial for the adoption of the Neolithic

economy. It is evident, therefore, that an understanding of possible variations in the climate of the British Isles during the Holocene will form a significant part of the elucidation of the environmental history and palaeoecology of the Lizard Peninsula.

The Blytt-Sernander classification of the European Holocene (in Roberts 1989, p.88) established a pattern of climate based on peat stratigraphy that was widely used for many years. It divided the Holocene into Pre-Boreal, Boreal, Atlantic, Sub-Boreal and Sub-Atlantic where Boreal represents cooler drier conditions and Atlantic warmer and wetter. Subsequently these have been variously dated, for example Pre-Boreal/Boreal ca. 11600–9000 years BP, Atlantic ca. 9000–5000 years BP, and Sub-Boreal/Sub-Atlantic, ca. 5000 years BP to preindustrial (Nesje and Dahl, 1993). Godwin constructed his pollen zones around these broad climatic sub-divisions (Godwin, 1975) and together they provided a well established framework for understanding climate and vegetational change in northwest Europe. As more data became available, however, the Blytt-Sernander classification largely went into disuse and the spatially variable and time-transgressive (non-synchronous) nature of vegetational change has now been well demonstrated (e.g. Wendland & Bryson, 1974; Lamb, 1977; Birks 1989).

Wendland & Bryson (1974) used radiocarbon dated pollen, sea level and cultural changes to identify global synchronicity of discontinuities in these records. Their analyses identified broadly synchronous cultural and environmental discontinuities with significant time lags between botanical and cultural changes. They also indicated time-transgressive vegetational changes, however, the time range over which they occurred increasing in the more recent samples, possibly due to the larger sample population. Lamb (1977) used the available evidence to divide the Holocene into three climatic stages, a rapid warming from 12000 to 8000 years BP, a period of highest warmth from 8500 to 5500 years BP and a period of cooling from 5500 years BP to the present. Summer and winter temperature change patterns were very similar and there were clear signs of centennial variation during the most recent period where larger amounts of data were available. Birks (1989) showed how tree migration routes from their refugia responded to a changing climate, firmly establishing the time-transgressive and spatially variable nature of vegetational change within the broader

pattern of climate change, even within a relatively small area such as the British Isles.

There are now an abundance of proxy climatic indicator data available and, alongside a greater understanding of natural forcings (orbital shifts, solar output, volcanic activity, land cover and greenhouse gases) and the use of powerful climatic models, a more detailed picture of Holocene climate variability is emerging. An overview of the position regarding the mid to late Holocene climate has been provided by Wanner *et al.* (2008). Following an extensive analysis of the available data from multi-proxy climatic indicators including ice cores, speleothems, foraminifera, chironomids, stable oxygen isotopes, tree rings, pollen and many others, and the results from General Circulation Models (GCMs) and Earth System Models of Intermediate Complexity (EMICs), six questions regarding the mid to late Holocene climate were tackled.

The first question considered the spatial structure of climate change during the period. A weakened orbital forcing in the northern hemisphere (NH) summer was identified that caused the Inter Tropical Convergence Zone (ITCZ) to shift south so initiating a summer cooling trend from the mid Holocene. At its coolest this is argued to have resulted in the Maunder Minimum of ca. 1600-1700 AD in the middle of the Little Ice Age (LIA), when glaciers throughout the NH reached their maximum extent. The second question involved the identification of multi-century cycles of cold/warm or humid/dry climates. Cooling on a ca. 1500 year cycle was identified but with a non-uniform temporal and spatial distribution. Cycles of neoglaciation were also found but they were highly variable and often not synchronous. The third question addressed the time scale of large-scale climatic shifts but no 'rapid or dramatic climate transitions' (Wanner *et al.*, 2008, p.1818) were identified.

The correspondence between known variations in natural forcings and climate variations was considered, and on the millennial scale insolation changes resulting from the orbital shifts of the Croll-Milankovitch cycles were deemed as the dominant factor. Solar energy redistribution was responsible for the southward shift of the ITCZ for example, but the effect was largely confined to the NH. The orbital effects in the southern hemisphere (SH) appear to be muted by oceanic heat transport. Apparent coincidence of solar variability

with proxy-climate variability clusters was not considered to be sufficient evidence for linkage, with Debret *et al.* (2007) identifying solar activity as only part of the explanation along with variations in ocean currents, atmospheric changes and changes in the geomagnetic field. A similar conclusion was reached for the effects of volcanic forcing where dramatic small scale cooling (2-3 years) following a tropical volcanic eruption can be identified from tree ring data. These occur against a background of much larger scale changes resulting from orbital and solar forcing and can therefore be considered only partially responsible for last millennium cooling intervals, including the LIA. Miller *et al.* (2012), however, suggest that the LIA was triggered by four large volcanic events over a fifty year period that caused the Arctic sea ice to expand. The cooling was sustained by sea ice export initiating a sea-ice ocean feedback for many centuries after the volcanic aerosols had disappeared.

Also an important contributor to climate is the natural variability such as the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO). These have been shown by computer models (e.g. Bengtsson *et al.*, 2006) to be more important than external climate forcings and a frequently underestimated cause of regional climate variations. But on the millennial timescale these sources of natural variability are, themselves, changed by orbital forcing. Finally it was concluded that climate models were able to simulate variability on both the millennial and the decadal to multi-century timescales. On the millennial timescale orbital forcing and its effects on the ITCZ, ENSO and NAO produced substantial climate changes, particularly in the NH where significant cooling occurred during the late Holocene, alongside increasing dryness and desertification in Central America, North Africa and the deserts of Eurasia. On the smaller decadal and multi-century time scales the complex climate variability indicated by the proxy-climate records is probably much more significantly affected by climate forcing factors such as solar activity and volcanoes, changes in oceanic circulation and feedback mechanisms between ocean, atmosphere, ice cover and vegetation. There is little evidence that these changes occur in cycles, however.

In the late Holocene, variations in the NAO have recently been linked to the Medieval Climate Anomaly (MCA) (Trouet *et al.*, 2009). This was a period of relative warmth over the North Atlantic/European sector ca. 800-1300 AD and was followed by the LIA that is

usually considered as commencing in the 14th century and continuing until ca. 1850 AD. The driving mechanisms of these events are uncertain and the possible links to volcanic eruptions suggested by Miller *et al.* (2012) have been set out above. Trouet *et al.* (2009) have used a tree-ring based drought reconstruction from Morocco and a speleothem based precipitation proxy from Scotland to extend the instrumental NAO record back to ca. 1000 AD so encompassing most of the MCA. This indicates a positive NAO during the MCA with a clear shift to weaker NAO conditions in the LIA. Comparison to modern analogues suggests an MCA to LIA drop in winter temperatures of up to 0.5°C. The most likely mechanism to have caused this change in the NAO is considered to be changes in the tropical sea surface temperatures (SST). These views are consistent with Miller *et al.* (2012) if the triggering mechanism for the reduced tropical SSTs can be shown to be volcanic eruptions.

A similar review to that of Wanner *et al.* (2008) of proxy-climate records from the mid to the late Holocene has been undertaken by Charman (2010). In this case all the data were sourced from the British Isles with the emphasis on continuous records where the rate and magnitude of change can be assessed over centennial time periods. Charman points out that most of the climate-proxies from the region are a measure of water balance rather than temperature and therefore reflect precipitation minus evapotranspiration (P - E). He suggests that the important centennial scale changes in the climate of the British Isles over the past 4.5 millennia have been changes in precipitation rather than temperature. There is 'muted' evidence of a change to cooler, wetter conditions at ca. 4200-4000 years BP and much stronger evidence both in magnitude and coherence at ca. 2800-2700 years BP, ca. 1500 years BP and ca. 600 years BP. The evidence suggests that these and other changes in the climate of the British Isles, such as increased storminess indicated by sand dune records, are linked to changes in ocean circulation in the North Atlantic associated with an increase in ice rafted debris and lower SST, an echo of the views set out above. The strength of the links between P-E changes and North Atlantic SST suggest that ocean current changes were a significantly greater driver of increased precipitation in the British Isles than temperature changes. Other recent reviews of proxy-climatic data (e.g. Debret *et al.*, 2007; Wanner *et al.*, 2008) support this view suggesting a much more complex relationship between solar

forcing and climate dynamics, solar variability resulting from orbital changes having more significant millennial affects. Indeed, Charman observed that changes in P-E in the British Isles do not always occur simultaneously with temperature changes.

An interesting addition to the palaeoclimate debate comes from the work of the dendrochronologist Baillie (2007) and others. Baillie has suggested that the disciplines of history, archaeology and palaeoecology do not give sufficient weight to the evidence for dramatic impacts on climate by catastrophic events such as volcanic eruptions and interactions with comets. He has drawn on evidence from many disciplines to support this view, in particular from myths, human socioeconomic changes and tree ring anomalies. This viewpoint has been criticised, for example by Buckland (1997) who argued that the implication of causality in correlated events is rarely supported by sufficient data. The catastrophe theories nevertheless have many adherents (e.g. McCafferty & Baillie, 2005; Burgess, 1989) prepared to demonstrate that cultural changes and migrations in human populations in both the prehistoric and early historic period can be linked with catastrophic events.

The millennial, centennial and even smaller scale climate changes of the Holocene are now much better understood and are shown to be the result of the complex interaction of a wide range of factors, of which solar forcing resulting from orbital changes has the most significant millennial scale affects. Climate change on centennial and even decadal scales, however, is possibly the more important for its impact on human socioeconomic change but a much better understanding of this will require more reliable dating and greater interdisciplinary cooperation.

1.8 Significance to thesis

This review of the current literature reinforces the observations of Caseldine (1980) and Straker (2011) that the southwest of the British Isles, particularly Cornwall, is under-represented in the palaeoecological records. This has resulted from the lack of over-

deepened glacial depressions, the frequent disturbance of sites as a result of tin streaming and other anthropogenic activities, and the rarity of blanket bog in Cornwall due to the relatively low altitude and warm temperatures. In addition, those sites in Cornwall that have been investigated frequently lack radiocarbon dating. All of these difficulties are true of the Lizard Peninsula.

The two pollen archives on the Lizard Peninsula that have already been investigated are both from river valley outlets along the west coast of (see section 1.4.3 and Appendix II). Church Cove in Gunwalloe, investigated by French (1996), provided a 7.5 metre sediment core but it was not radiocarbon dated. Palynological investigation showed a very weak Ericaceae signal so providing little evidence of heathland development and the basal samples show an *Alnus/Quercus/Corylus* dominated woodland that may not be indicative of the plateau due to its low valley site. The second site 6 km north of Church Cove in Porthleven Harbour provided a 2.7 m peat core with a basal peat ^{14}C date of about 3,600 cal. years BP (Environment Agency, 1999). Again the Ericaceae signal was very weak and the basal samples were dominated by the pollen of *Alnus*, *Quercus* and *Corylus*. These two archives therefore provide little evidence of either the possibility of a pre-anthropogenic forest on the plateau or the development of the heathland.

Relatively extensive archaeological investigations indicate the presence of human populations on the Lizard Peninsula from the Mesolithic period onwards. The evidence for this is summarised in Berridge & Roberts (1986), Mercer (1986), Christie (1986) and Quinell (1986). There is a general consensus in these summaries of the importance of the peninsula in prehistory as a source of minerals and Harrad (2004) has demonstrated its importance as a source of grabboic clay during the Bronze and Iron ages. 'Snap-shots' of the Bronze Age landscape from Polcoverack to the east of the plateau and Goonhilly Downs are provided by the analysis of palaeosols (Smyth, 1974; Smith, 1984b). They indicate an open landscape of grasses, *Plantago* and sedges with extensive Ericaceae dominated heathland and a tree and shrub cover of hazel, alder and some oak, ash and elm, greater than the present. This is confirmed by Crabtree (in Hopkins, 1983, p.39) in his analysis of a Bronze Age burial

palaeosol from the peninsula. This also contained 'a trace' of *Erica vagans* pollen but none was found in the other samples.

In summary the importance of the archaeology on the Lizard Peninsula and its evidence for the presence of significant human populations, particularly during the Bronze Age, is poorly supported by palaeoecological reconstructions. The sites that have been investigated provide very limited information on the vegetation of the plateau, the development of heathland, the status of *E. vagans* or the pre-anthropogenic landscape. They provide us with an indication of the valley vegetation at current sea levels from the Bronze Age onwards and brief glimpses of the Bronze Age landscape of the plateau. There is therefore a need to find new Holocene archives that provide a more extensive chronology of vegetational history from the pre-anthropogenic landscape to the present, and of the plateau from which much of the current archaeological evidence has been gathered.

1.9 Techniques in palaeobotany

Sediment samples were collected and prepared for analysis by standard field and laboratory techniques as described by Moore *et al.* (1991), Faegri and Iversen (1989) and the protocols described by the University of Cambridge Geography Department Laboratory Services (University of Cambridge, 2012). Absolute pollen counting will be conducted using *Lycopodium* spores according to Stockmarr (1971). Pollen and spores will be identified using the keys within Moore *et al.* (1991), Faegri and Iversen (1989), Andrew (1984) and reference collections when available. The 'Paldat' pollen identification website (Paldat – Palynological Database) and its associated text (Hesse *et al.*, 2009) will also be used to support written keys. The Ericaceae pollen will be separated into species as far as possible using the keys in Oldfield (1959). Pollen diagrams will be drawn using the computer programmes PSIMPOLL 4.25 and PSCOMB 1.03 as described by Bennett (2005) and the C2 software as described by Juggins (2010).

Surface samples will be prepared from moss polsters gathered at the study sites as described

by Moore *et al.* (1991, p.35) and prepared and counted using the techniques used for the organic sediments but with a shorter period of acetolysis and no HF treatment. Charcoal fragments of two size categories will be counted using the slides prepared for pollen and spore counting.

Macrofossil analysis will be carried out on the long Hendra core (HEN3) using the technique described in Birks and Birks (1980, chapter 5) and using the macrofossil descriptions of Beijerinck (1947) and Brecht (1941).

1.10 Thesis objectives and structure

As set out at the start of this chapter the aims of this thesis are as follows:

- i. To determine the nature of the pre-anthropogenic landscape on the Lizard Peninsula plateau. More specifically to establish whether or not the plateau was forested and if so the nature of the forest.
- ii. To trace the origins and development of the heathland vegetation and to determine the extent of the human contribution to this development.
- iii. To gather evidence of the history of the endemic Ericaceae *Erica vagans* on the peninsula in order to inform the debate as to the origins of this species in the post Devensian recolonisation of the area.

To address these goals palynomorph archives on the peninsula plateau were selected that filled all or some of the following criteria:

- They contain a record dating back to beyond 5000 year BP in order to establish the nature of the pre-anthropogenic landscape.
- Their location is within or close to the current areas of heathland.
- They contain an accessible palynomorph archive enabling, in particular, Ericaceae species to be distinguished.

The thesis is set out in five further chapters. Chapter 2 describes the search for study sites with a detailed description of the four sites selected for close analysis; their geology, ecology, human influence and significance to the thesis. Chapter 3 discusses the techniques employed in the study of the four sites, both the background development of the techniques and their strengths and limitations. Specific questions arising from these techniques relating to this research are also addressed.

Chapter 4 presents the results of the investigations at the four sites. These encompass sediment descriptions, palynological diagrams and macrofossil analysis. The core from the Lizard Downs site contained no palynomorphs so no further analysis beyond the sediment description was conducted. The Erisey Barton site and the Croft Pascoe site concentrate upon the analysis of a single sediment core. Three cores from the Hendra site were analysed, two for palynomorphs and one for macrofossils.

Chapter 5 provides an interpretation of the data from each of the three sites from which palynomorph and other evidence was obtained. This is followed by an overview linking all the evidence from these three neighbouring sites and relating it to palaeoecological, archaeological and palaeoclimatic evidence from the literature. The support provided for existing interpretations of the palaeoecology of the Lizard Peninsula is highlighted, as are those findings that do not have a precedent and may constitute a new understanding. The concluding Chapter 6 considers the relationship of these findings to the vegetational history and archaeology of Cornwall and the southwest, the possible value of this research to the development of conservation strategies on the peninsula and the opportunities for further research.

The year numbering system that will be followed throughout most of this thesis, in common with the majority of Quaternary studies, is to give dates as years before present (BP) meaning years before 1950 AD. For dates in the 11th to 20th centuries, however, dates are given as AD to allow ready comparison with historical accounts, and elsewhere where it facilitates comparisons AD/BC dates are given in brackets. The plant taxonomy throughout the thesis is based on Stace (1999).

Chapter 2 STUDY SITES

The search for suitable sites for palynological investigation commenced in the spring of 2003. Initially any possible sites of Holocene sediment accumulation on the peninsula were visited with the intention of selecting the most suitable sites from those identified as possibly having a Holocene archive. The Lizard OS soil survey map, sheets SW 61/71 (Staines, 1984) was an important source with six areas of 'miscellaneous peat soils' marked on the map. Five of these areas were investigated and these are described below. The sixth site at Trelease Farm (SW760213) could not be sampled due to the objections of the landowner. In addition to the sites from the soil survey map some of the west coast coves were investigated for the possibility of sediment deposition within their drainage features. A map of the Lizard peninsula showing the study sites, those visited but not subsequently forming part of the study and those that have been previously investigated appears in Appendix II.

An area at Crousa Downs (SW764188) identified as 'peat soil' by Staines (1984) was investigated but only 40 cm of highly oxidised material was found with clay beneath. Its potential was considered poor and it was not sampled. Also identified from the soil survey map were two adjacent areas of 'peat soil' just south of St Keverne. These were within the Withey Wood at the Roskilly ice cream workshop (SW797212). The longest sediment sample collected here was 61 cm. The top 10 cm consisted of a black/dark brown humified peat overlying 40 cm of light brown, less humified peat with a basal 10 cm of minerogenic clay-silt. A core was extracted and spot sampled, and slides prepared by acetolysis for counting. The palynomorph assemblage over the first 30 cm was found to be dominated by *Salix*, *Quercus* and *Poaceae* pollen, with *Equisetum* and *Pteropsida* spores. There was only a minimal *Ericaceae* signal, however, and its location 6.5 km to the east of the heathland and the serpentine resulted in this site being excluded from further work as being unlikely to contain a useful heathland archive.

Mullion and Polurrian Coves on the west coast were visited (SW667178 and SW668188) but the valleys were considered too narrow and steep for significant deposition. Poldhu and

Church Coves (SW663199 and SW661204) north of Polurrian were considered as having more potential for Holocene studies but were considered too far north to provide useful data regarding heathland development. A pollen diagram from Gunwalloe at Church Cove has previously been published (French, 1996). Tregarne Farm near Porthallow (SW787232) is indicated on the soil survey map (Staines, 1984) as having an area of 'peat soil' and 70 cm of highly organic silt/clay was found. Although having potential as a Holocene archive with suitable HF treatment, it was not further investigated due to its location 6 km NE of the plateau heathland and so, as with the Roskilly site, unlikely to contain a heathland archive.



Figure 2.1 Lizard peninsula, Cornwall showing the four study sites. The two areas of heathland, Lizard/Lower Predannack Downs to the south and Goonhilly Downs to the north appear brown against the largely green patchwork of farmland (Google Maps). [See also Appendix II.]

Two of the areas identified in the soil survey map were considered to have potential and were suitably located near Goonhilly Downs. These were near Hendra Farm (SW711175)

just south of Goonhilly Downs and near Erisey Barton Farm on the southern edge of Goonhilly Downs (SW713187). A chance observation of a drainage flush near Croft Pascoe Forest on the top of Goonhilly Downs resulted in the identification of a third suitable site (SW729190). The fourth and final site that subsequently formed part of this study was identified in the autumn of 2004 during the investigation of the drainage channels on Lizard Downs (SW692142). The four sites that form the basis of this study are shown above on Fig. 2.1

2.1 Lizard Downs

2.1.1 Location, geology and geomorphology

Lizard Downs is an extensive area of heathland to the southwest of the peninsula. Along with Lower Predannack Downs it extends from Predannack Airfield in the north to the outskirts of Lizard village in the south. Lizard/Lower Predannack Downs is one of the two



Figure 2.2 The main drainage channel separating Lizard and Lower Predannack Downs dominated by *Salix* spp. and *Phragmites australis*. 'Tall Heath' in the foreground is dominated by *Schoenus nigricans*, *Molinia caerulea*, *Erica vagans* and *E. tetralix*

remaining extensive areas of heathland on the peninsula, the other being Goonhilly Downs. Like Goonhilly it is situated on the serpentine and is part of the Pliocene plateau with a gentle north-south slope from 85 m OD in the north to 75 m OD in the south. The Downs are dissected by two drainage channels, a 700 m long channel from Kynance Farm (SW680146) draining into the sea at Soap Rock (SW676144) and a much longer channel to the south. It extends approximately 3 km from the Hayle Kimbro Pool (SW694169) north of the Downs draining into the sea at Kynance Cove (SW685132). The channel incises the plateau deeply over the final 1 000 m with a less incised profile inland (see Fig. 2.2).

The soils on the plateau belong to the Croft Pascoe series; coarse silty and loessic drift over serpentine alternating with stony serpentinitic soil, the latter found particularly in the valleys. Close to the coastal cliffs and in the deeply incised valleys the silty soils are replaced by stony, loamy serpentinitic soils (Staines, 1984).

A core was extracted from a small basin adjacent to the main drainage channel of the Downs, about 1.2 km upstream from its exit at Kynance Cove. The site was 69 m above OD, grid reference SW 6928714292. 70cm of sediment were obtained from this first site, dark grey, poorly humified, penetrated by roots and with a high mineral content. About 200 m further down the channel at 63 m above OD, grid reference SW 6910714161, 80 cm of sediment were obtained from a larger basin, 30 cm of poorly humified grey/brown organic mud overlaying 50 cm of grey, fine silty-clay.

2.1.2 Ecology and human influence

Lizard Downs is dominated by heathland species corresponding to the 'Rock Heath' community of Coombe *et al.* (1956) along the exposed coast around Kynance Cove, 'Mixed Heath' along the sides of the valleys and predominantly 'Tall Heath' on the plateau (see section 1.4). These correspond to the H7, H6 and H5 community descriptions of the NVC (Rodwell, 1991). The main drainage channel is dominated by *Salix* spp. along the edges and

Phragmites australis along the channel (see Fig. 2.2). Other species present within and adjacent to the channel are *Schoenus nigricans*, *Juncus effusus*, *Molinia caerulea*, *Sanguisorba officinalis*, *Ulex europaeus* and *Erica vagans*.

Excavations at Windmill Farm at the northern edge of Predannack Downs indicate that the area was used by Mesolithic people as an autumn and winter 'base camp' (Smith, 1984b). Thomas (1960, 1969) provides evidence for a Bronze Age settlement at Kynance Gate and the OS map (OS Explorer 103, 1996) indicates an ancient settlement at this point, on the northern bank of the main channel about 800 m above the Kynance outfall. Talc deposits at Gew-graze at the outfall of the northern drainage channel, are reported by Bristow (2004, p.80) to have been exploited in the 18th and early 19th centuries and traces of the old works can be seen here at Soap Rock. This is corroborated by Parkinson (1993) who records the issuing of licences to mine Soap Rock at 'Chynance' to Viscount Falmouth in 1751. Over much of Lower Predannack Downs a largely abandoned field system is present. Kynance Farm cottages and two abandoned cottages about 500 m to its south are evidence of current and recent agricultural activity in the area. The cottages were apparently abandoned in the 1940s (Duncan Lyne, NE, 28.05.04, pers. com.). At best the Downs can be classed as having marginal agricultural value and it appears that the area progressively depopulated during the 20th century. The most noticeable agricultural activity at the time of writing is the grazing of the heathland area by highland cattle.

2.1.3 Significance to thesis

One of the research aims is to investigate the origins of the heathlands of the Lizard peninsula. To this end it was considered important to obtain palaeoecological data from both Lizard Downs and Goonhilly Downs. Small sediment filled depressions along the course of the main drainage channel of Lizard Downs provided the opportunity to investigate possible palaeoecological archives.

2.2 Erisey Barton

2.2.1 Location, geology and geomorphology

The ‘Erisey Barton’ site is situated at 65 m above OD, on the southern edge of Goonhilly Downs, 750 m due north of Erisey Barton farm, grid reference SW713187. It was initially identified when an area of ‘miscellaneous peat soils’ shown about 600 m south of the site of the dam on the OS Soil Survey map of the Lizard, SW61/71 (Staines, 1984) was investigated (see Fig. 2.3) .

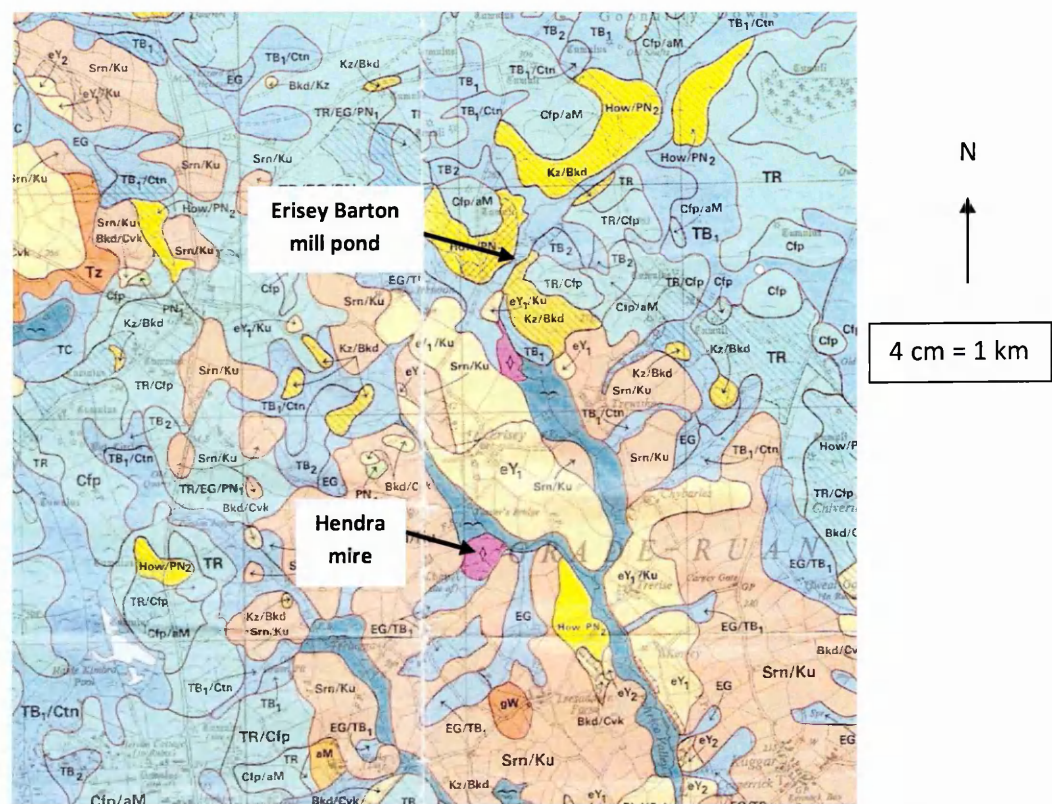


Figure 2.3 Section of OS soil survey map ‘Lizard’ Sheets SW 61/71 (Staines 1984) showing two purple areas of ‘miscellaneous peat soils’. The northern area is just south of the Erisey Barton mill pond site, the southern area is the Hendra mire feature. For the full key to soil types see Staines (1984).

The Erisey Barton site appears to be a sediment filled mill pond behind an ancient dam. Robert Gilbert of Erisey Barton farm, the landowner, believes it is one of two dams of

possibly 16th century origin (June 03, pers. com.). This has not been corroborated and subsequent investigations suggest that there has been a dam at this site for almost 1 000 years. The farm itself is situated on an area of granite gneiss within the much larger area of serpentine. The dam and sediment filled millpond are on the serpentine. The site is situated in a narrow valley about 15 m below the 80 m plateau to the east and west (see Fig. 2.4 below). The stream within the valley drains from the 100 m above OD Goonhilly Downs plateau, the high point of which is about 1.3 km to the northeast of the site.

The soil types indicated by the soil survey map (Staines, 1984) are complex at this point. The valley has cambic gley soils described as stony with fine serpentinitic silt overlying the



Figure 2.4 Aerial view of Erisey Barton dam (arrow A) with *Salix cinerea* ssp. *oleifolia* scrub immediately behind the dam (arrow B) and a sediment filled millpond above this. Arrow C shows sampling site. The stream flows SW off Goonhilly Downs to the NE. (Google Maps)

serpentine. The rocky slopes to the west have stagnogleyic ranker soils, stony with loamy serpentinitic soils passing to serpentine. The rocky slopes to the east have a soil classed as a brown ranker, also described as stony, loamy serpentinitic passing to serpentine.

A stream still flows through the centre of the valley but to either side of this the surface is very dry suggesting that the mire is no longer actively growing. A sediment core of 131 cm was removed from the centre of the valley about 40 m upstream from the *Salix* scrub. The upper 77 cm was identified as *Phragmites* peat, dark brown and humified for the upper 4 cm becoming lighter brown and less humified with depth and grey brown for the basal 30 cm. From 82 cm – 116 cm the sediment was an organic clay/silt becoming stiffer, less organic and very gritty from 116 cm – 131 cm. 20 m downstream towards the dam the depth of unhumified brown peat declines to about 36 cm with grey brown peat grading into grey organic clay/silt beneath this to the base at about 110 cm.

2.2.2 Ecology and human influence

The old dam shown in Figure 2.5, is approximately 35 m in length. The area immediately behind is dominated by *Salix cinerea* ssp. *oleifolia*. The vegetation in the sediment filled channel and valley upstream of the *Salix* scrub consists of *Phragmites australis*, *Eriophorum* spp., *Osmunda regalis* L., *Filipendula ulmaria* (L.) Maxim., *Juncus* spp., *Plantago* spp., *Ranunculus repens* L., *Pteridium aquilinum* (L.) Kuhn, *Sanguisorba officinalis*, *Angelica sylvestris* L., *Hydrocotyle vulgaris* L., Poaceae spp. and Cyperaceae spp. The rocky sides of the valley, particularly to the east, are colonised by a Mixed Heath community dominated by *Ulex europaeus* and *Erica vagans*.

The fields to the south of the site are currently actively utilised as part of the Erisey Barton livestock farm. Erisey Manor House is named after the Erisey family that can be traced back to 1274 and the gate post is dated 1671 (Oaks, 1946). The earliest record for 'Erisey Mill' is 1757 in association with 'Old Mill Pond Leat' (Peter Dudley, CAU, 26.09.06 pers. com.). It can therefore be assumed that relatively intensive agricultural activity has an extended presence here. There is evidence from aerial photographs for old field boundaries in the immediate vicinity of the site, those to the east with repeated furrow strips indicative of



Figure 2.5 The rock faced dam above Erisey Barton farm with *Salix cinerea* scrub behind the dam, *Ulex europaeus* in the foreground and Mixed Heath on the rocky slope to the east.

ploughing (see Figure 2.4). The field boundaries also appear on the OS map (Explorer 103) but there are fewer to the immediate north where the land levels off and slopes up towards the top of the plateau where there are none. It appears that at the time of writing there is no agricultural activity taking place around the site and the mills that once operated utilising the millpond have not been active for at least 150 years as there is no mention of them on the 1841 Tithe Map. The apportionments on the Tithe Map do specify field use as 'furze' however, the collection of mostly gorse for burning.

2.2.3 Significance to thesis

An important aim of this thesis is to study the heathland development of Goonhilly Downs, one of the last two remaining areas of heathland on the peninsula. The Erisey Barton site is on the southern edge of the Downs and should provide a high resolution archive of the changes in the heathland structure since the establishment of the millpond as long as 800

years ago. It may also provide evidence of human activity and climatic induced changes during the historical period.

2.3 Croft Pascoe

2.3.1 Location, geology and geomorphology

The 'Croft Pascoe' site is situated at approximately 95 m above OD, slightly east of the centre of Goonhilly Downs adjacent to Croft Pascoe Forest. It is a wet, linear feature of unknown origin approximately 600 m in length identifiable for 300 m of this length by a strip of *Phragmites australis* (Fig. 2.6). It is situated on the Goonhilly Downs serpentine plateau, sloping gently to the south at this point from 95 m OD at the northern end to about 89 m OD at the southern end of the 300 m feature. The high point of the plateau at 110 m is approximately 2 km to the NW at the Goonhilly Earth Station.



Figure 2.6 The Croft Pascoe linear feature marked by a band of *Phragmites australis*. Croft Pascoe Forest is to the left and the *Salix* carr to the centre left.

The feature commences in an area of *Salix cinerea* carr directly adjacent to the road linking the B3294 with Kuggar village, opposite the Croft Pascoe Forest, grid reference SW7301019226. The sampling site is approximately 300 m to the SSW grid reference SW7296519031. The *Phragmites* dominated area terminates just beyond this point but the aerial photograph (Figure 2.7) indicates that the feature continues for about another 250 m.

The sediments within the *Salix* carr are thin and underlain by a grey clay. 150 m south of this northern extremity of the feature it narrows to 30 m, and has a much less developed willow scrub cover. The sediment deepens to 56 cm, 23 cm of light grey/brown peat overlying 33 cm of mottled, dark grey/orange yellow stony clay. 50 m south of this it narrows to about 17 m with fewer species but with the appearance of *Athyrium* sp. The sediment depth here remains at about 50 cm with 33 cm of mid-brown peat underlain by 17 cm of dark grey/blue-green mottled clay. A further 40 m south the width is reduced to about 7 m with 36 cm of sediment, 30 cm of mid-brown peat with clay below. It narrows to about 5 m a further 30 m south with a very thin (<10cm) depth of organic material before the bedrock. 20 m further south it widens again to 25 m with a sediment depth of as much as 86 cm in places. It is from this section that the Croft Pascoe core, CPAI, was extracted. A further 30 m south, the feature reduces to about 10 m in width with about 30 cm of wet organic sediment and loose boulders above the bedrock. The wet channel continues beyond this point for a further approximately 250 m bifurcating into smaller radiating channels. *Phragmites australis* is replaced by *Schoenus nigricans* as the dominant species moving southwards along the channel. A 3D diagram based upon transects across locations at 25 m intervals along 275 m of the feature are shown below in Figure 2.8. The raw data from the transects appears in Appendix VII.

2.3.2 Ecology and human influence

The heathland at Croft Pascoe conforms to the 'Tall Heath' classification of Coombe and Frost (1956), H5 in the NVC classification. It is dominated by *Erica vagans*, *Schoenus nigricans*

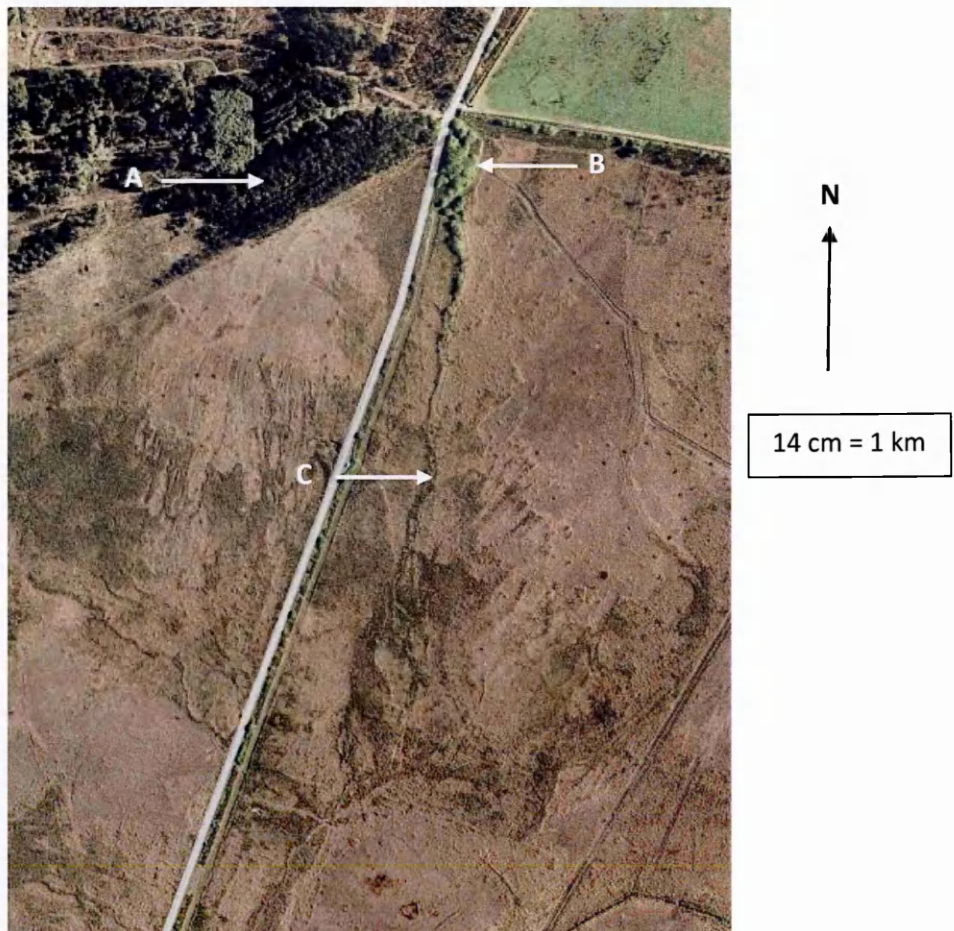


Figure 2.7 The Croft Pascoe linear feature extending from the *Salix* carr (arrow B) adjacent to Croft Pascoe Forest (arrow A) for 300m SSW to a point adjacent to the lay-by where the CPA1 core was extracted (arrow C). The feature continues for a further 250 m bifurcating into a number of smaller channels. The water flows from N to S. (Google Maps)

and *Molinia caerulea* with *E. tetralix*, *Ranunculus lingua* L., *R. repens*, *Cirsium arvense* (L.) Scop., *Sanguisorba major*, *Angelica sylvestris*, *Lychnis flos-cuculi* L., and *Epilobium* spp. also present. *Phragmites australis*, *Salix cinerea* and *Athyrium filix-femina* (L.) Roth occur along the wet, linear course of the feature with *Ulex europaeus* along the edges. The Croft Pascoe plantation is dominated by Corsican Pine, *Pinus nigra* var. *maritima*. A few trees of *Quercus petraea* (Matt.) Liebl., Sitka spruce, *Picea sitchensis* (Bong.) Carrière and Lawson Cypress, *Chamaecyparis lawsoniana* (A.Murray bis) Parl., also occur in the forest with *Salix cinerea* and *Ulex europaeus* around the entrance and along the forest tracks. *Rubus fruticosus* L., agg. and *Lotus pedunculatus* Cav. are abundant in these disturbed areas. Natural England currently manage

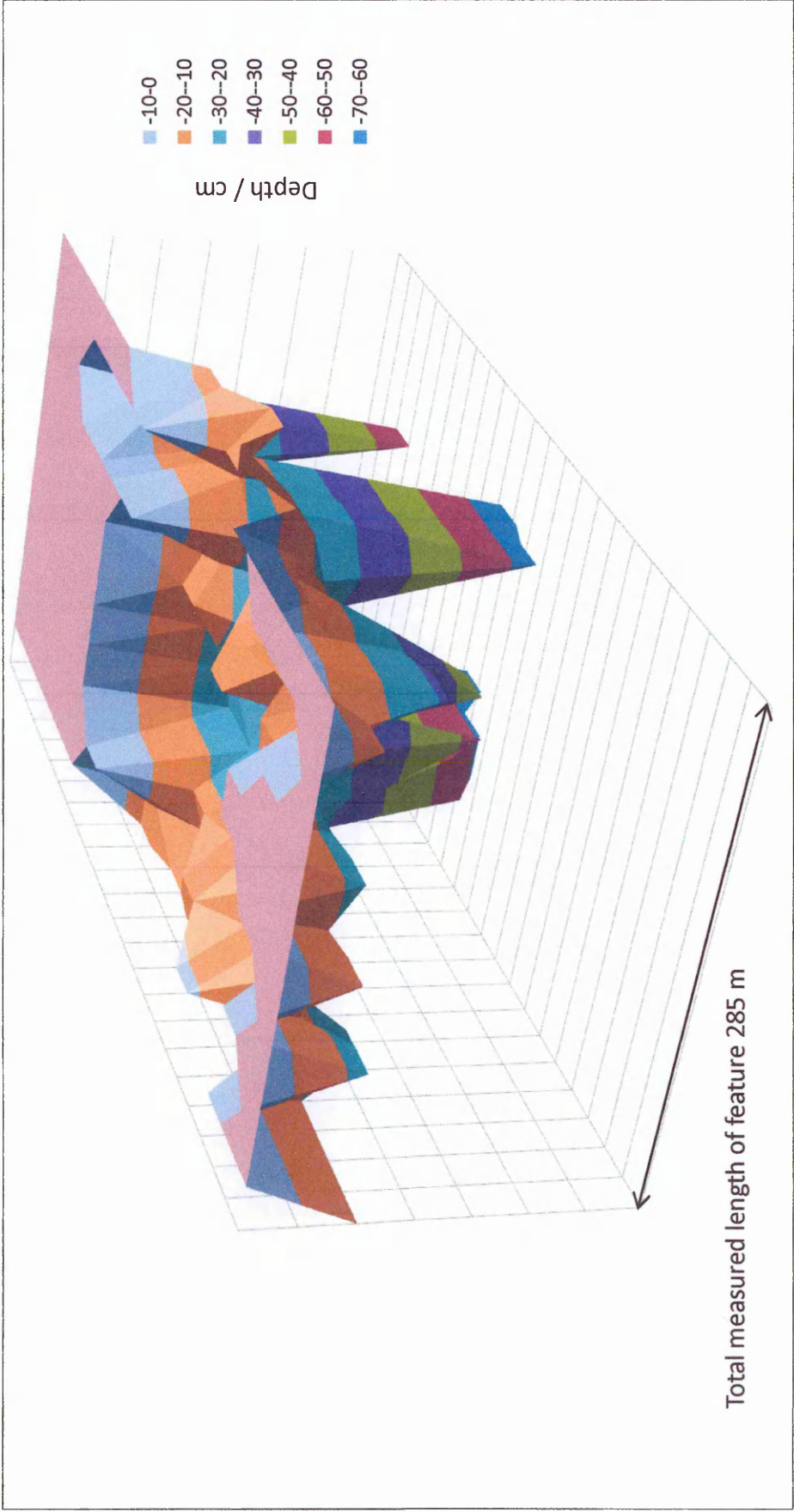


Figure 2.8 Croft Pascoe transect 3D diagram - depth exaggerated, length compressed (raw data Appendix VII)

the heathland by periodic burning, although much of the burning in the area results from arson (Duncan Lyne, NE, 28.05.04, pers. com.).

In his excavations on Goonhilly Downs, Smith (1984b) identified a high concentration of Bronze Age burial mounds suggesting high occupation status in the Middle and Late Bronze Age. Christie (1986) links this to possible metal exploitation. Halliday (1954) describes the importance of peat and turf cutting on the Downs, the 'Turbaries', during the medieval period continuing up until the 17th century (see section 1.4.3).

The initial survey above and the aerial photograph and transect diagram (Figures 2.7 and 2.8) show a slightly 'wandering' linear feature with a width and depth varying apparently randomly from 20 m at its widest to 8 m at its narrowest, and 10 cm at its shallowest to 80 cm at its deepest. Beyond the end of the 300 m feature the channel reduces in width and has a minimal sediment depth (<20 cm) finally bifurcating into a number of smaller channels. The area was heavily cut for turf in the medieval era and this may have accelerated the water-logging of the feature. It is unlikely to have been cut for peat drainage as it would have channels joining it in a herringbone structure (Peter Dudley, CAU, 26.09.06, pers. com.). The ¹⁴C calibrated date for 50 g of the basal sediment is 4152±254 years BP placing it in the Late Neolithic/Early Bronze Age. The transects indicate a feature with deep pits and shallow regions (Fig. 2.8). These observations point to a plausible explanation for the origin of the feature as a surficial lode excavated during the Late Neolithic/Early Bronze Age for copper or tin leaving a linear depression subsequently filled with sediment. The chronology of Pearce and Burgess (in Christie, 1986, p.82) places the first copper axes in Cornwall just before the ¹⁴C date of these basal sediments. The fall of the land along the feature has resulted in some flow of water through it during wet periods forming the long drainage 'tail' or 'fan' beyond the 300 m point as visible on the aerial photographs (Fig. 2.7) and on the ground following the wet summer of 2012. This possibility is supported by the observations of Smith and Christie (1986) and will be investigated further.

2.3.3 Significance to thesis

The Croft Pascoe site is centrally placed on Goonhilly Downs and so offers the possibility of an extended record of climatic and anthropogenic vegetational change and heathland development on the summit of the peninsula. The work of Smith (1984b) suggests that the area had a significant Bronze Age human population and the possibility that the feature is related to Bronze Age mining or agriculture will be investigated.

2.4 Hendra

2.4.1 Location, geology and geomorphology

The Hendra site is situated at 54 m OD, approximately 500 m due south of Erisey Barton Farm, and 500 m due east of Hendra farm, grid reference SW711175. It is about 2.6 km southwest of the Croft Pascoe site. It was initially identified from the Lizard Soil Survey map (see Fig 2.3 above). It lies in a shallow valley with a stream along its northeastern edge that drains into the Poltesco valley 500 m to the southeast. It is accessible from Friar's Lane, initially by a public footpath, and is approached from the west via a deep drainage ditch. The stream adjacent to the feature rises from higher ground about 800 m to the northwest. The *Phragmites* dominated surface of the basin is approximately 7,000 m² in area with a maximum measured sediment depth of 1.8 m. It is located on the serpentine with a small area of granite gneiss to the north beyond the stream. Directly on the northeastern edge of the feature are the alluvial gley soils adjacent to the stream channel with stagnogleyic and gleyic brown earth soils to the southeast and northwest. It appears to be an uneven depression filled with a largely organic sediment. An aerial photograph (Fig. 2.9), GIS elevation diagrams (Fig. 2.10) and transect depth data (Fig. 2.11) appear below. The depth data show that the depression continues to both the northeast and the southwest of the current *Phragmites* dominated surface. The elevation and 3D diagrams (Fig. 2.10) indicate that the depression was originally part of the drainage channel but the present day stream largely bypasses it. These data are best explained by the hypothesis that this is a periglacial feature in which a wide drainage channel has been carved out by melt-water at this point. This has

subsequently been bypassed by the stream leaving an abandoned terrace with alluvial, overbank or channel infill sedimentation. The water table remains high due predominantly to seepage from the stream.

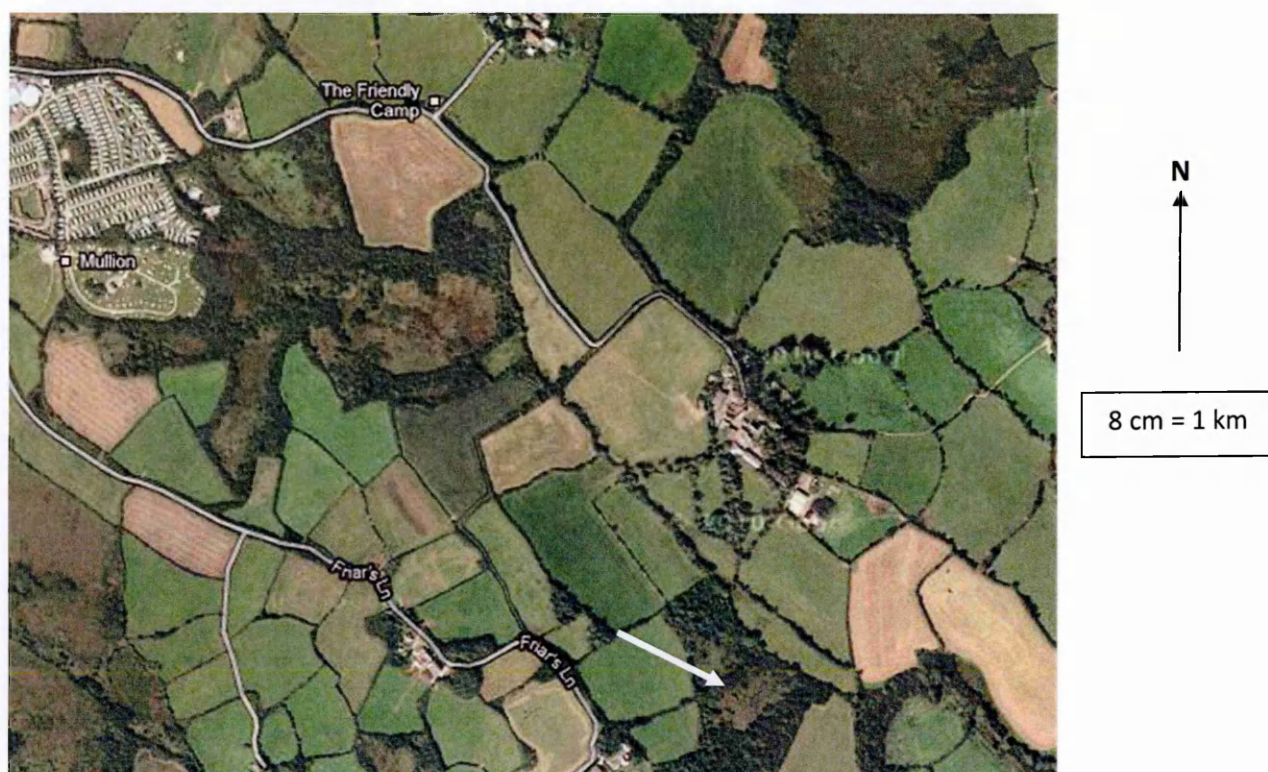


Figure 2.9 The Hendra mire feature (arrowed) with the main catchment for the feeder stream to the northeast adjacent to the caravan park (Google Maps).

The top 10 -15 cm of the sediment consists of highly humified organic detritus underlain by fibrous, highly organic mud. The basal 20 to 30 cm consists of an organic, bluish-grey clay becoming increasingly clayey and minerogenic with depth.

2.4.2 Ecology and human influence

There is little evidence for flowing water on the surface of the feature so it is possible that the most recently accumulated organic material has grown above the level of the stream to

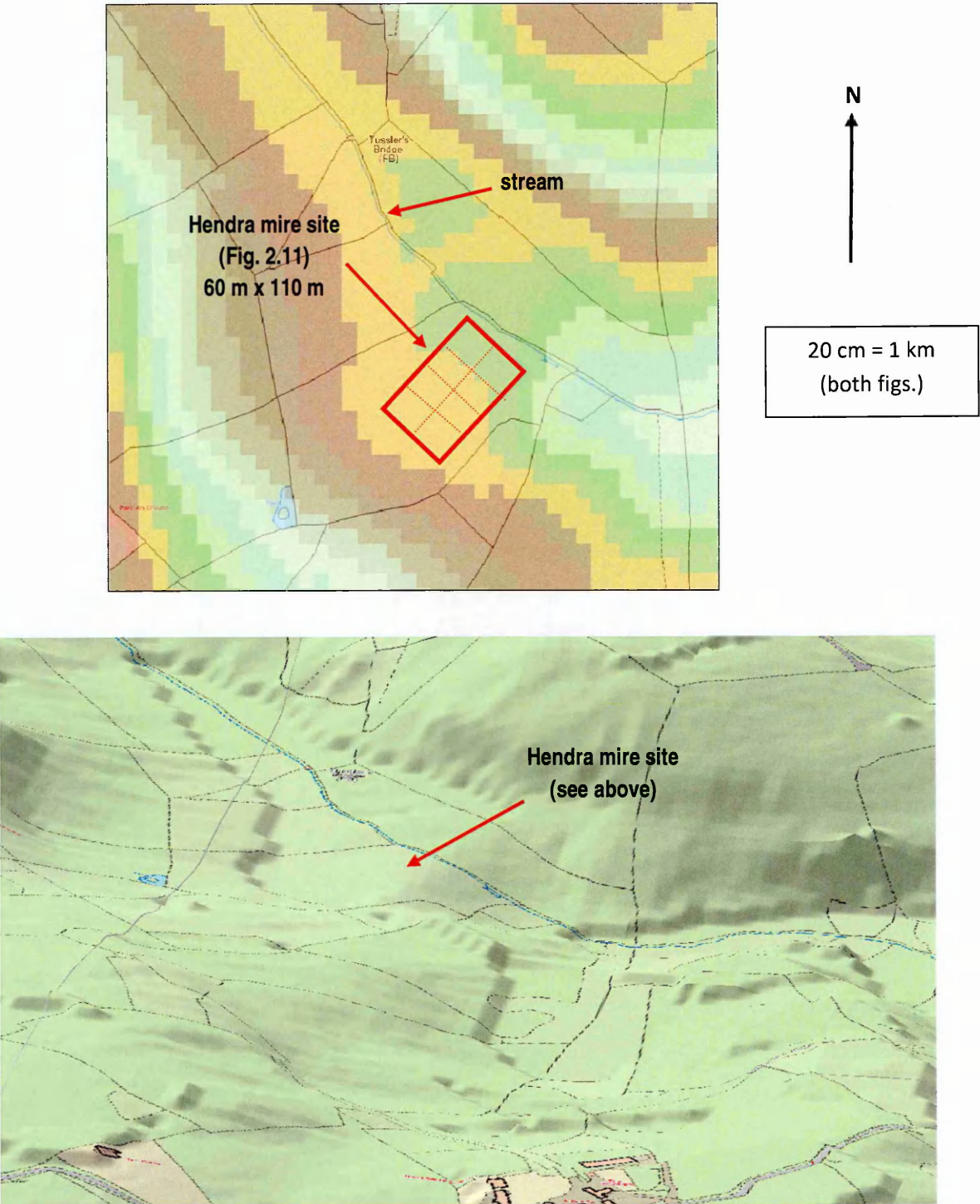
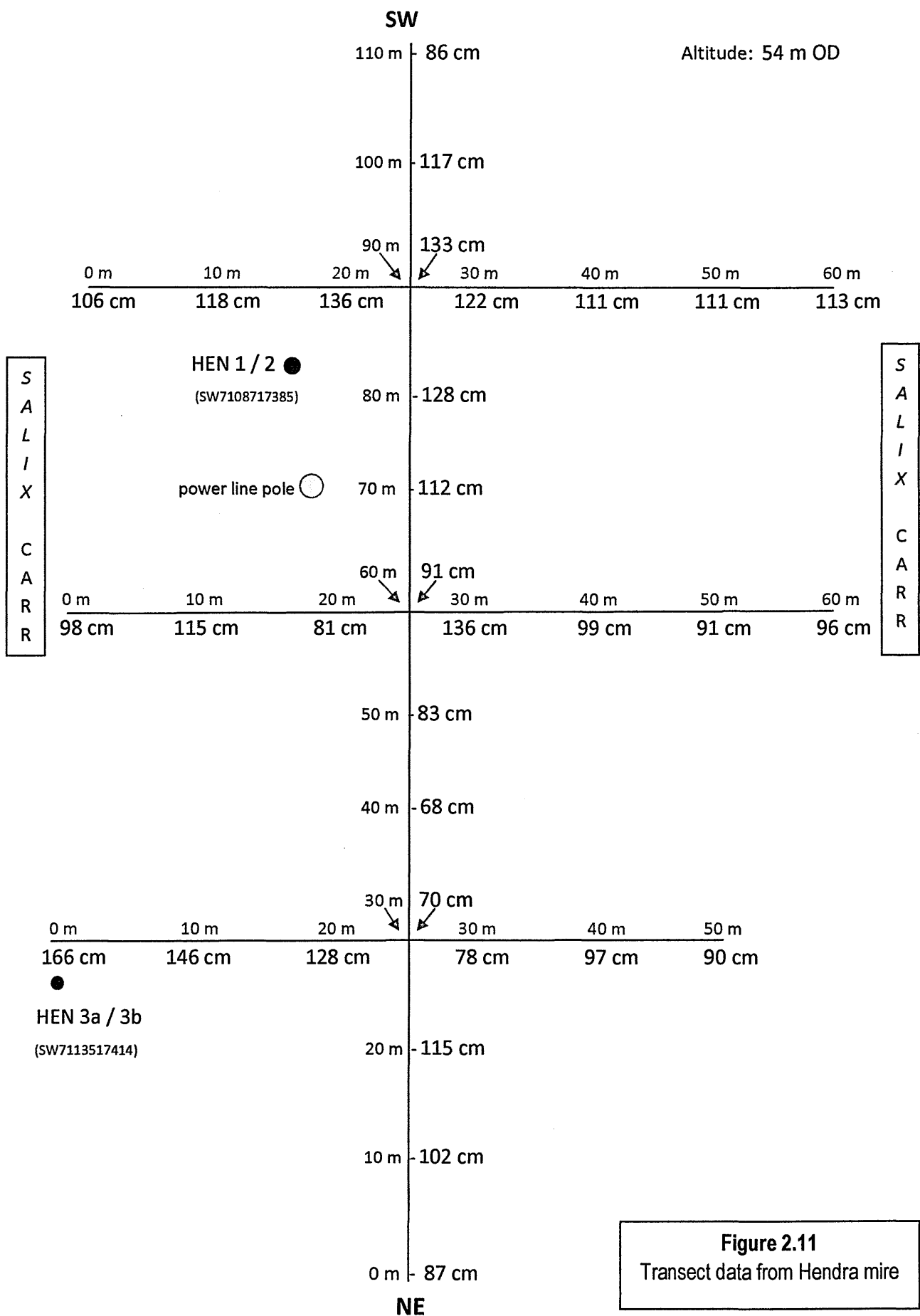


Figure 2.10 GIS maps of Hendra site in valley tributary of Poltesco valley.
TOP: Elevation map, colour changes represent 1 m elevation intervals.
BOTTOM: 3D effect map (exaggeration x5), Hendra site (arrowed).



the north. The permanent presence of surface water, however, and the nature of the surface vegetation suggest a rheotrophic mire, so it may be assumed that it has not risen above the limit of the winter water table. The surface of the feature is densely covered by *Phragmites australis*. Other species present include *Salix cinerea* ssp. *oleifolia*, *S. caprea* L. and *Ulex europaeus* around the fringes, and *Oenanthe crocata*, *Angelica sylvestris*, *Iris pseudacorus* L., *Eupatorium cannabinum*, *Scrophularia* spp., *Molinia caerulea*, *Sanguisorba officinalis*, *Hydrocotyle vulgaris*, *Potentilla erecta*, *Lotus pedunculatus*, *Cirsium palustre*, *Juncus effusus*, *Mentha aquatica* L., *Lychnis flos-cuculi*, *Filipendula ulmaria*, *Hypericum tetrapterum* Fr., *Lythrum salicaria* L. and *Anagallis tenella* (L.) L. extending onto the surface of the feature. In 2010 the scarce *Juncus subnodulosus* Schrank was discovered growing on the site (see Appendix III), its only location in Cornwall (Bennallick, 2010). Figure 2.12 shows the burnt surface of Hendra mire in February 2006.

The earliest reference to the site found is on the 1878-9 OS map where it is described as a 'willow bed'. The area around the site is currently actively farmed with cattle frequently



Figure 2.12 The burnt surface of Hendra mire in February 2006. The burnt material is predominantly *Phragmites australis*, still unburnt to the left. The burnt trees are *Salix* spp. with *Salix* carr surrounding the feature and standards of *Quercus* sp. beyond.

present when the site has been visited. However, the considerable difficulty in accessing the site suggests that there has been no recent anthropogenic exploitation of the pond area other than the passing of a small electricity line overhead via a wooden pole close to the centre of the pond. The recent confirmation of *J. subnodulosus* and a population of Marsh Fritillaries on the site have raised the possibility of Natural England seeking a 'Higher Level Stewardship' agreement for it (Ian Bernalick, 04.2011, pers. com.).

2.4.3 Significance to thesis

As a result of its location approximately 1.2 km south of the edge of Goonhilly Downs the Hendra sediments are unlikely to contain a clear archive of heathland development. The depth of sediment and the possibility that this began to accumulate early in the Holocene, however, offer the prospect of a record of the vegetation extending beyond the Neolithic. This archive may therefore address the research question regarding the nature of the pre-anthropogenic landscape and may contain an aeolian allochthonous pollen signal from the two areas of heathland, Goonhilly Downs to the north and Lizard Downs 4 km to the southwest.

Chapter 3 FIELD AND ANALYTICAL TECHNIQUES

3.1 Collecting and sampling the sediment cores

The first visits to the sites took place in the spring and summer of 2003 when a 50 cm x 3 cm gouge auger was used to make an initial assessment of the nature and depth of the sediments. Spot samples were taken from the longest cores at each site at 10 cm intervals and sealed into labelled polythene bags. Following the construction of pilot diagrams high quality cores were collected in the spring of 2006 using a Russian corer and a 1 m x 4 cm gouge auger. Cores from Lizard Downs, Erisey Barton, Croft Pascoe and Hendra were collected over a two day period, wrapped in cling film and foil and transported in plastic guttering. In May 2010 a further 10 cm diameter core was collected from the Hendra site.

At Lizard Downs one site (LDA1) was sampled with a total of three cores taken, within 0.5 m of each other at the first site described in section 2.1.1. These consisted of two Russian core sections, 10 cm - 50 cm, and 9 cm - 56 cm, and one gouge auger core, 0 cm - 70 cm.

At Erisey Barton two sites were sampled. The first site (cores EBA1 and EBA2) was as described in section 2.2 above. All the cores here were collected with a Russian corer. Three core sections were taken from EBA1, 0 cm – 50 cm, 50 cm – 100 cm and 80 cm to 130 cm. A few meters from EBA1 a second sequence of four overlapping core sections (EBA2) were taken, 0 cm – 25 cm, 25 cm – 75 cm, 75 cm – 125 cm and 55 cm to 105 cm. From a second site, about 10 m north of the first and to the west of the stream in *Cladium* peat, a second series of core sections were taken (EBB1). These consisted of three core sections with the Russian corer, 0 cm – 30 cm, 19 cm – 69 cm and 7 cm – 57 cm. A few metres away a second core (EBB2) was taken using the 1 metre gouge auger of 0 cm – 88 cm.

At Croft Pascoe four core sections were collected from a site almost adjacent to (slightly to the north of) the Natural England lay-by (grid ref in Sec. 2.3 above). The first two were

taken with the Russian corer, 30 cm – 66 cm and 52 cm – 86 cm. Two gouge auger cores were then taken, 0 cm – 70 cm and 54 cm – 87 cm.

A total of eight core sections were collected at the Hendra site. The coring site on both the initial visit and the subsequent coring operation was towards the southwest of the feature close to the centre line (SW 71087 17385, see Fig. 2.11) and about 10 m SE of an electricity pole (SW 71135 17414). Three were collected with the Russian borer (HEN1), 0 cm – 50 cm, 50 cm – 100 cm and 73 cm – 123 cm. A further three gouge auger core sections (HEN2) were collected approximately 1 m from HEN1. They were 25 cm – 125 cm, 0 cm – 80 cm and 0 cm – 90 cm. Following the construction of the transect a deeper section of sediment was identified near the southwest corner of the pond. A 10 cm diameter core was collected from the top 116 cm of sediment using a makeshift piston corer made from drainage pipes modified for the purpose. The end that was driven into the sediment was sharpened and the other end was drilled to accept a rod to assist in the lifting. The first section of drainpipe was 120 cm in length and the top 77 cm of sediment was successfully lifted out in it. The second 180 cm drainpipe was pushed down the same hole and a further 39 cm was lifted out (topped by 23 cm of sludge from digging). To assist in the lifting of the samples a shovel was used to lever the pipe up and a gouge auger was driven into the core to release the pressure. The final 1 m (compressed to 83 cm) was collected using a Livingstone corer. The cores were removed from the drainpipes using a 'piston' comprised of a food can of just under 10 cm diameter. The two 10 cm diameter core sections were designated HEN3a and the Livingstone core HEN3b.

Moss polster samples were collected from the Croft Pascoe and the Hendra sites for the estimation of current pollen and spore frequencies (surface samples). The polsters from Croft Pascoe site were collected from around the bases of the ferns in the wet section of the feature. The polsters from the Hendra site were collected from the branches of the *Salix* trees growing on the surface of the mire.

The nature of the sediments within in all the core sections was described and recorded using the Troels-Smith (1955) sediment description system described in Birks and Birks

(1980), Faegri and Iversen (1989), Jones *et al.* (1999) and Moore *et al.* (1991). The cores were then stored at ambient (unheated garden shed) temperatures and the Russian corer and gouge auger core sections sampled as required with the removal of approximately 5 g of material away from the edge of the core at each depth. At a later stage, due to concerns over the storage temperature, the lower sections of the HEN1, HEN2 and CPA1 cores were sliced into 1 cm segments and stored at 5°C in labelled plastic bags. The 10 cm HEN3 cores were spot sampled at 5 cm intervals for later pollen analysis, about 5 g of sediment for each sample. Part of the remainder of the core was then sampled as described for the macrofossil analysis.

3.2 Preparation of the sediment for analysis

The samples for the pilot diagrams were prepared at Cornwall College laboratories using a protocol from the Department of Geography at the University of Cambridge compiled by William Gosling (see Appendix I). No hydrogen fluoride (HF) facilities were available so this section of the protocol was omitted. High levels of minerogenic material at the lower levels made microscopic analysis very difficult.

For the final diagrams most of the preparation was conducted at the School of Ocean Sciences laboratories at the University of Bangor. Initially their standard laboratory protocol was followed involving HF extraction followed by acetolysis (see Appendix I). Low pollen densities resulted in a switch for later samples to the Godwin acetolysis (see Appendix I) following the HF treatment. Some of the samples from the top 50 cm of the Hendra core were prepared using the restricted protocol at the Cornwall College laboratories and occasional batches from Bangor in which cellulose material still hampered the pollen counting process were given further acetolysis treatment at Cornwall College. Eight samples were prepared at the University of Exeter (Tremough) laboratories using sediment partly prepared at the Cornwall College laboratories (NaOH digestion and sieving) followed by HF treatment and acetolysis at Tremough (see Appendix I). This mixing of the protocols may have been responsible for the loss of two of the samples and for two others being of

little value. It is speculated that incompatible sieve mesh sizes for the double sieving protocol followed at Tremough may have been the cause of the difficulty.

One or two *Lycopodium* spore tablets from Lund University were added to each of the samples used for the final diagrams. These were from two different batches (see Appendix VI). The University of Cambridge protocol was followed for the preparation of the moss polsters using a shorter acetolysis and no HF treatment (see section 1.8). Two samples were prepared at each of the two sites sampled.

3.3 Fossil pollen and spores

Quantitative reconstruction of past vegetation is the goal of pollen analysis although it began as a predominantly qualitative discipline. Since the pioneering work of early researchers such as von Post and Godwin, however, the process has been refined through many studies including the analysis of differing pollen representation (R-values) and production rates (e.g. Davies, 1963; Andersen, 1970), the factors that affect pollen dispersal and deposition (e.g. Tauber, 1965; Jacobson and Bradshaw, 1981) and factors affecting preservation and stratification of pollen once deposited (e.g. Clymo, 1965, 1973). More recently these refinements have been enhanced by their incorporation into numerical models of pollen data, made more powerful by the use of numerical models such as POLLSCAPE developed by Sugita (1994) and adopted as the central tool for POLLANDCAL, an international research network focusing on this topic. This uses algebraic descriptions to model the pollen/vegetation relationship and so generates numerical estimates of past vegetation. Other approaches use present-day assemblages as analogues (e.g. Calcote, 1998). With the rapid increase in desktop computer power and speed, these techniques have been the basis for readily available software such as HUMPOL (Bunting & Middleton, 2005) and the Multiple Scenario Approach (MSA) software suite (Bunting & Middleton, 2009).

These computer models still depend upon certain assumptions that have always underpinned the interpretation of pollen diagrams (Lowe & Walker, 1997, p.163; Bunting & Middleton,

2009). The first of these is that a palynomorph represents a taxonomic level which is low enough to have a recognisable and consistent ecological requirement. Second, that the environmental parameters associated with the taxon identified are uniform over the time period studied and that both present analogues and past plant and animal distributions are in equilibrium with their controlling environmental factors. Finally the models of pollen productivity, dispersal and deposition that inform the interpretation should be correct and unchanging through time.

The first of these assumptions depends primarily on the successful identification of the palynomorphs. This is determined by observations of size and shape, the nature of the exine (pollen outer shell), surface ornamentation and the number and type of apertures. The correct identification of these depends in turn on the state of preservation such that bias may occur if palynomorphs of different taxa have differential states of decay or respond differentially to laboratory preparation. Thus successful interpretation of pollen diagrams depends both on the security of the identification of the palynomorphs and the care with which the necessary assumptions are applied.

3.3.1 *Counting technique and pollen and spore identification*

The material was mounted in silicon oil on labelled slides and the pollen and spores identified and counted during one way 'left to right' tracking using a Leica DM1000 microscope. A magnification of x400 was used for tracking and x1,000 with anisole immersion for critical grains. Phase contrast was also used where appropriate. Count sheets developed in the sub department of Quaternary Research at the University of Cambridge were used throughout, modified where necessary to take account of novel taxa (Appendix I).

For identification purposes the keys and websites listed in Section 1.8 were used extensively. A library of digital photographs of 'type' grains, particularly of those where identification was problematic, was built up using a Canon 'Power Shot' S50 digital camera with a Leica microscope attachment. In critical cases digital images were used to seek second opinions

from colleagues. Pollen preservation was quite poor in many sections of the cores and this needs to be taken into account when detecting possible bias in the diagrams. The degree of preservation of different samples can be estimated by the records of 'indeterminate' pollen and spore shown on the pollen diagrams.

3.3.2 *Ericaceae* pollen, morphology and identification

The identification of the *Ericaceae* species in the pollen assemblages forms a very important part of this investigation. It serves as a proxy to trace the origins and relative abundance of *Erica vagans*, and to study the composition of the heathland ericaceous flora through time. *Ericaceae* pollen are tetrads, tectate or semitectate, tricolpate and with a variety of surface ornamentation. A reference collection of *Ericaceae* pollen from the Lizard peninsula heathland was prepared and used to support the key and detailed descriptions in Oldfield (1959). Following the production of the pilot diagrams three categories of ericaceous pollen that could be confidently identified were selected. They are described below using the dimensions shown in Figure 3.1.

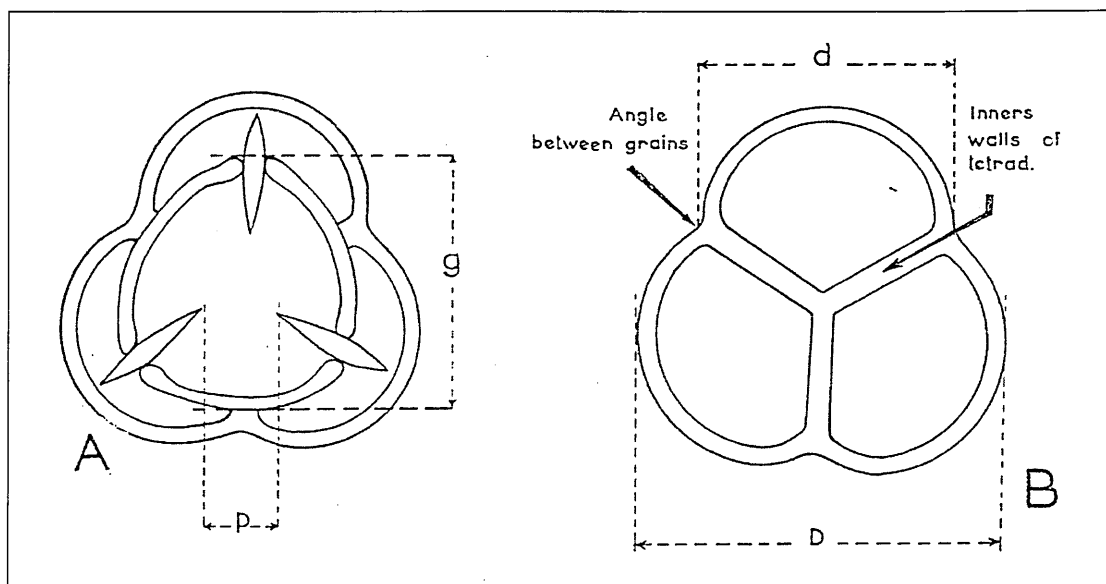


Figure 3.1 Dimensions used in describing tetrads (from Oldfield, 1959)

i) *Calluna vulgaris*

This is the most variable of the ericaceous pollen encountered. At its widest ('D' in Fig. 3.1) it ranges from 31-60 μm and a single tetrad unit (dimension 'd' above) 28-41 μm (Oldfield, 1959). The range in the specimens encountered in this study were largely at the smaller end of this scale, possibly as a result of the use of silicone oil in the preparation of the slides for this study. The smallest were recorded as $D = 35 \mu\text{m}$ and the largest at $D = 50 \mu\text{m}$. Oldfield (1959) points out the unreliability of the metric data, however, suggesting that fine morphology is a better guide than size statistics. The *C. vulgaris* tetrad is often irregular and it has a 'very coarse granular' exine giving a 'rough look' with furrows, when visible, being 'short and jagged' (Andrews, 1984). Another important feature that sets it apart from the remaining tetrad pollen is that the four elements of the tetrad are often visible in the same plane, or may be encouraged to assume this position by pressing the cover slip of a silica gel mounting (Michael Grant, 5.04.09, pers. com.), see Figure 3.2 below.

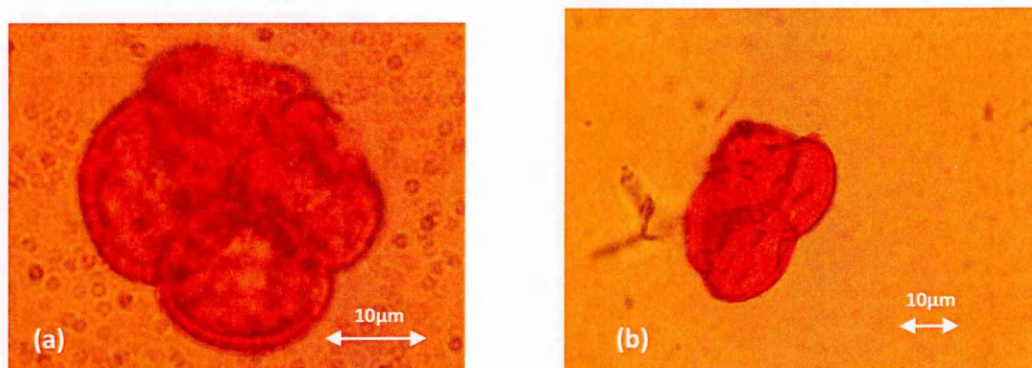


Figure 3.2 *Calluna vulgaris* pollen from the Lizard peninsula. (a) EBA2 70 cm, $D = 30 \mu\text{m}$
(b) HEN1 55 cm, $D = 38 \mu\text{m}$

The three features most frequently used in the identification of *C. vulgaris* pollen were the rough 'double cobbly wall' (Andrew, 1984), the frequently observed single plane of the tetrad elements and the lack of symmetry of the tetrad. Figure 3.2 shows *C. vulgaris* pollen for which a very confident identification decision was possible. However, due to the poor state of preservation of many specimens, particularly due to crumpling, the identification was less confident and occasionally *C. vulgaris* grains may have been classified as 'Ericaceae undiff.'.

ii) *Erica vagans*

The pollen of the endemic *Erica vagans* was relatively easily separated from the remaining ericaceous pollen. It is a small grain, $D = 26\text{--}33\text{ }\mu\text{m}$, $d = 16\text{--}23\text{ }\mu\text{m}$ and $D/d = 1.3\text{--}1.6$ (Oldfield, 1959). It has very thick almost smooth walls, neatly bound furrows (when visible)

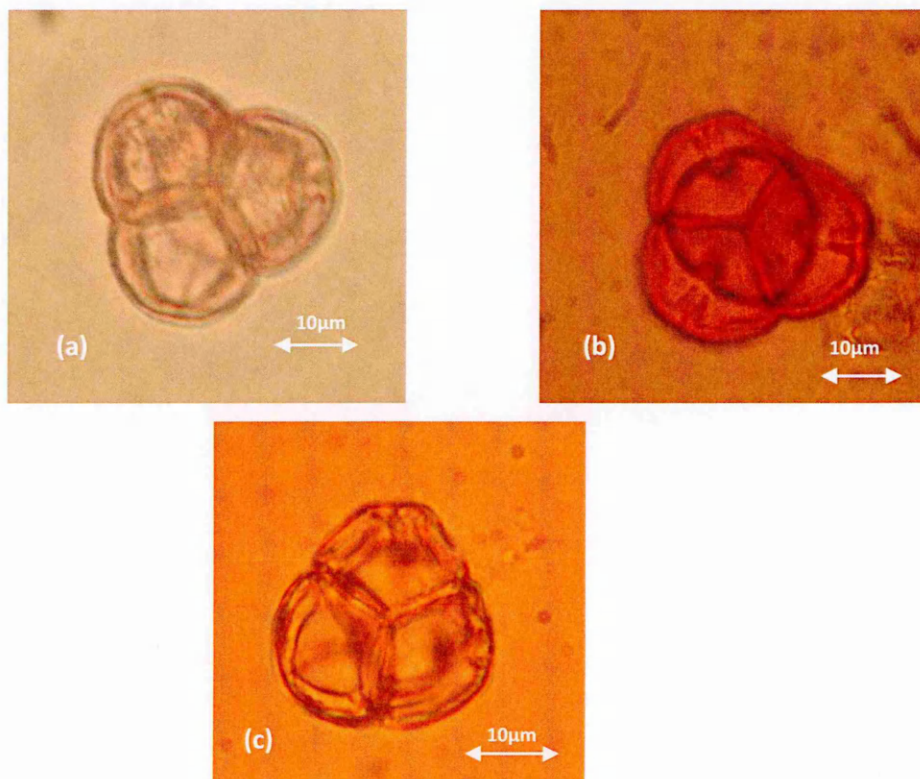


Figure 3.3 *Erica vagans* pollen from the Lizard peninsula. (a) Modern pollen grain $D = 30\text{ }\mu\text{m}$
(b) EBA2 35 cm $D = 29\text{ }\mu\text{m}$ (c) HEN2 115 cm $D = 24\text{ }\mu\text{m}$

and a very regular appearance, all four elements of the tetrad being of very similar dimensions arranged in a symmetrical tetrahedron. These features enabled a confident identification to be made even when the grain was poorly preserved. Figure 3.3 above shows a modern Lizard peninsula *E. vagans* pollen grain (a) alongside two fossil grains, (b) and (c). As with the *Calluna vulgaris* pollen the fossil *E. vagans* pollen encountered was largely at the smallest end of Oldfield's size range.

iii) Ericaceae undiff.

This final category contained predominantly *Erica tetralix*, *Erica cinerea* and possibly *Erica ciliaris* and *Empetrum nigrum* L. pollen, put together into this grouping as no confident separation of them could be made. The poor state of preservation of many of the grains meant that the coarser, more crackled exine of *E. cinerea* compared with *E. tetralix* and *E. ciliaris* (Oldfield, 1959) could not be confidently identified. Only the generally larger size of *E. cinerea* ($D = 38-56\ \mu\text{m}$) compared to *E. tetralix* ($D = 36-43\ \mu\text{m}$) and *E. ciliaris* ($D = 34-42\ \mu\text{m}$) and the smaller *Empetrum nigrum* ($D = 30-34\ \mu\text{m}$) may still distinguish them but the overlap in these size categories made this criterion unreliable. Pollen tentatively identified as *E. tetralix* is shown in Figure 3.4 below.

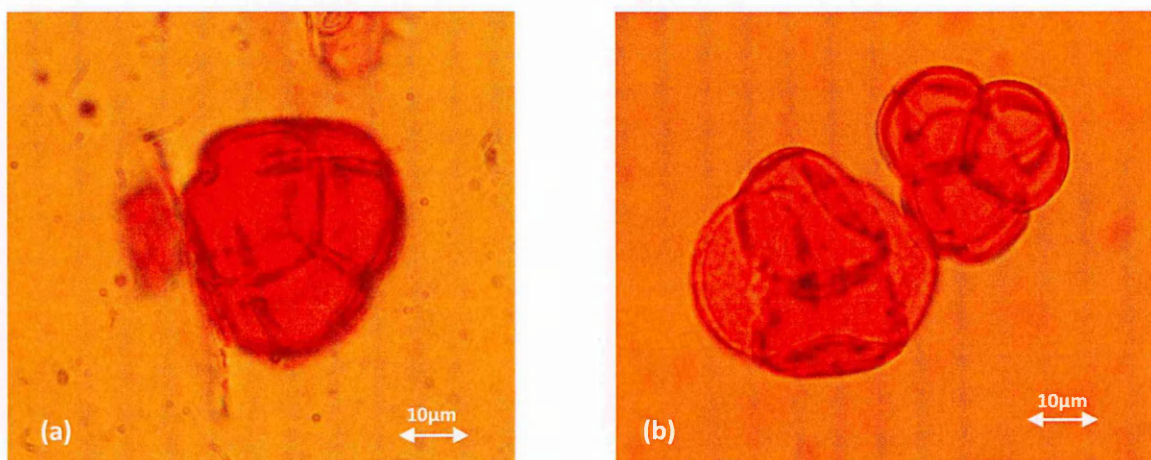


Figure 3.4 Lizard peninsula pollen from EBA2 80 cm. (a) Possible *E. tetralix* pollen $D = 38\ \mu\text{m}$
(b) *E. vagans* ($D = 30\ \mu\text{m}$) and *E. tetralix* ($D = 38\ \mu\text{m}$)

The other important element of this category is tetrad pollen that was too poorly preserved to be placed in either the *C. vulgaris* or *E. vagans* categories. This may have included tetrad pollen that did not belong to any of the ericaceous taxa described above.

3.3.3 *Poaceae* pollen, cereal grain identification

The anthropogenic element in the palaeoecology of the study area is a central part of this investigation. The interpretation of the palynological evidence therefore depends significantly on the identification of putative cultivated cereal pollen grains and their

separation from naturally occurring wild grasses. This is an area that has been studied by palynologists over many years (e.g. Firbas, 1937; Andersen, 1979; Küster, 1988; Beug, 2004; Tweddle *et al.*, 2005; Waller & Grant, 2012).

Poaceae pollen is tectate, spheroidal and with a single, annulated pore. Pollen of different species differ widely in diameter and have a fine granulate, scabrate, verrucate or microechinate surface structure. Firbas (1937) pointed out that cultivated cereal pollen was generally much larger than its wild relatives. Andersen (1979) refined this by also taking into account the annulus diameter, grain shape and surface sculpturing, and Küster (1988) added to this the importance of the ratio of the pore diameter to the annulus diameter and the thickness and appearance of the annulus. He suggested that the annulus diameter of cereal pollen is greater than double the pore diameter, that the annulus protrudes significantly in optical section, and that the annulus boundary is well defined. Beug (2004) used phase contrast microscopy to separate *Hordeum* type, *Triticum* type and *Avena* type by surface sculpturing. *Hordeum* and *Triticum* are identified by 'scabrate to microechinate....point-like elements' that are relatively evenly spaced on the surface of *Hordeum* grains but form groups on the surface of *Triticum* grains. *Avena* pollen grains have a more composite sculpturing consisting of larger elements forming 'polygonal fields'. In all these cases the patterning is formed by surface elements. He also compared the morphology of the pores as seen in optical section. Andersen (1979) described the *Hordeum* group as having a scabrate surface pattern and the *Avena-Triticum* group as having a verrucate surface pattern.

Tweddle *et al.* (2005) have applied a multivariate statistical analysis to the approaches of Andersen (1979) and Küster (1988) and concluded that greater confidence in identification of large Poaceae pollen can be obtained if the two different approaches are used in parallel or combination. This is the approach that has been taken here in the identification of sample grains from the three Lizard peninsula sites that form the basis of this study. In addition phase contrast microscopy has been used to study the surface structure where visible. The microechinate pattern described by Beug (2004) was observed in only 3 of the 12 grains studied (Fig. 3.5) and it cannot be ruled out that this appearance was an artefact. Such observations therefore have to be considered tentative. Consideration had to be made for

the decrease in the dimensions of grains mounted in silicone oil compared to those mounted in glycerol or glycerine jelly. Faegri and Iversen (1989, p.285) suggest a conversion factor of x1.1 to x1.3 for the increase in mean grain diameter, and x1.1 to x1.5 for pore data. Andersen (1979) used silicone oil preparations and Küster (1988) and Beug (2004) used glycerol preparations (Faegri and Iversen, 1989; Tweddle *et al.*, 2005). A conversion factor of x1.2 has therefore been used when comparing the Lizard Poaceae grains to the characteristic dimensions quoted by Küster and Beug.

i) Erisey Barton large Poaceae pollen

Six large Poaceae pollen grains (mean diameter >32 µm) selected from the Erisey Barton site at 85 cm depth were studied in detail. The data are shown in Table 3.1 below.

Table 3.1 Structural details of large Poaceae pollen grains from the 85 cm sample level of the Erisey Barton (EBA2) core.

No.	mean diam/µm	pore diam/µm	annulus		exine/µm	surface ornamentation	notes
			diam/µm	thick/µm			
1	50	5	12 distinct	-	1.2	microechinate, (grouped ?)	broken, Fig. 3.5
2	50	5	12 distinct	-	-	none visible	Fig. 3.6
3	33	3	8 distinct	-	-	none visible	-
4	41	3	15 distinct	3.2	1.2	none visible	Fig. 3.6
5	40	3	10 distinct	-	-	none visible	-
6	40	4	11 distinct	-	1.0	fine microechinate	-

Grains 1, 2, 4, 5 and 6 by dimensions (allowing for silicone oil preparation) correspond to the *Avena-Triticum* group of Andersen, the *Cerealia*-type (not *Glyceria*) of Küster, and *Triticum* or *Avena* according to Beug. The tentative observation of a microechinate surface structure as described by Beug on grains 1 and 6, with possible grouping on the surface of grain 1 (Fig. 3.5) suggest cultivated *Triticum* spp. as the most likely identification for these grains. The

particularly large size of grains 1 and 2 would suggest *T. spelta* as the most likely species. The optical section of the pore in grain no. 4 corresponds closely to that of *T. aestivum* described by Beug.

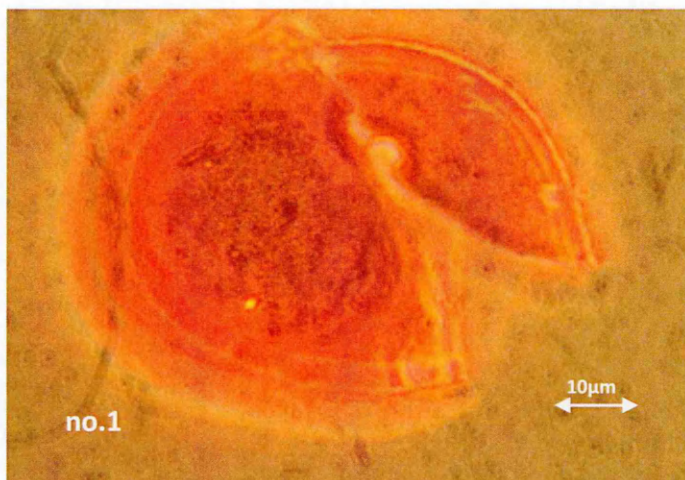


Figure 3.5 Erisey Barton Poaceae pollen no.1 (Table 3.1) x1000 phase contrast.
Microechinate/scabrate surface structure visible.

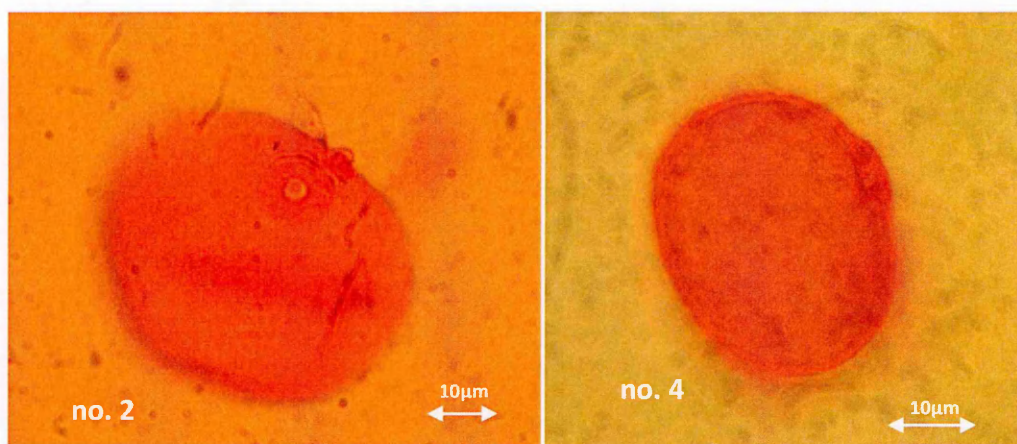


Figure 3.6 Erisey Barton Poaceae pollen nos. 2 and 4 (Table 3.1) x1000 (no. 4 phase contrast)

Grain 3 was significantly smaller than the remaining 5 grains and its mean diameter, pore and annulus dimensions corresponded to the *Hordeum* group of Andersen and Beug. As with the previous grains, Küster's observation of the annulus diameter being more than double the pore diameter in his *Cerealia*-type group rules out the possibility of *Glyceria* spp.

In summary there are strong indications that all six grains are from cultivated cereals, most probably of the *Triticum* genus in five cases with tentative observation of a microechinate surface structure increasing the security of this identification in two cases. In the sixth case the *Hordeum* genus is indicated. The overlap with wild grasses, however, particularly *Avena fatua*, the common wild oat, and wild species of *Hordeum*, means that the possibility of these grains not having been produced by cultivated cereals cannot be ruled out.

ii) Hendra large Poaceae pollen

Three large Poaceae pollen grains were selected from the 60 cm, 80 cm and 84 cm samples of the Hendra (HEN1) core. The data are shown in Table 3.2 below.

Table 3.2 Structural details of large Poaceae pollen from the Hendra (HEN1) core.

No.	depth/ cm	mean diam/ μ m	pore diam/ μ m	annulus		exine/ μ m	surface ornamentation	notes
				diam/ μ m	thick/ μ m			
1	60	45	4	13 distinct	3	1.2	microechinate, tightly packed elements, not grouped	Fig. 3.7
2	80	43	3	8 distinct	-	1.2	none visible	
3	84	40	3	10 corroded	-	2	none visible	Fig. 3.8

Pollen grain no.1 falls into *Avena-Triticum* group of Andersen and the *Cerelia*-type of Küster (not *Glyceria*). The dimensions are consistent with *Triticum* and *Avena* spp. in Beug but the microechinate surface structure supports the *Triticum* spp. identification as does the morphology of the pore. Grains 2 and 3 have smaller dimensions that fall into the *Hordeum* group of Andersen, the *Cerealia*-type of Küster (not *Glyceria*), and *Hordeum* spp. or some *Triticum* spp. (e.g. *T. monococcum*) in Beug.

In summary there is good evidence that the pollen grain at 60 cm depth is from the *Triticum* genus. Those from 80 cm and 84 cm are more securely identified as from the *Hordeum*

genus. In no case, however, can the identification be considered as firm and the possibility that the large Poaceae grains from the Hendra core have derived from wild grasses cannot be completely eliminated.

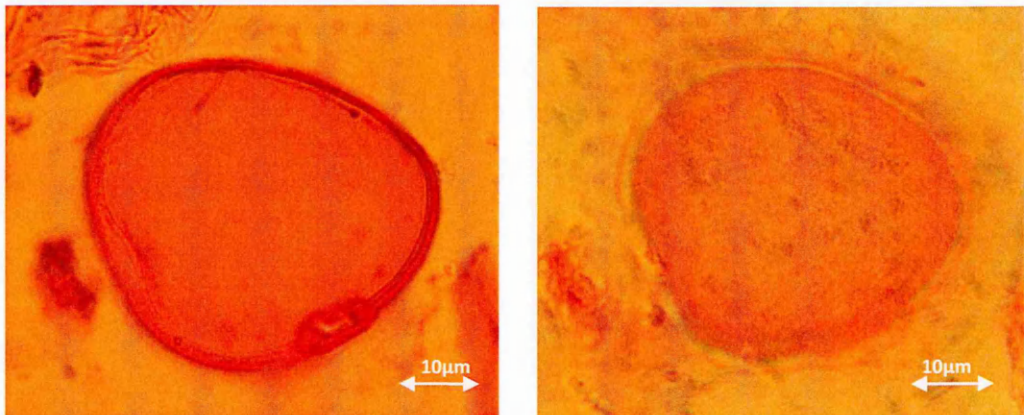


Figure 3.7 Hendra Poaceae pollen no.1 x1000, phase contrast (right) showing microechinate surface structure

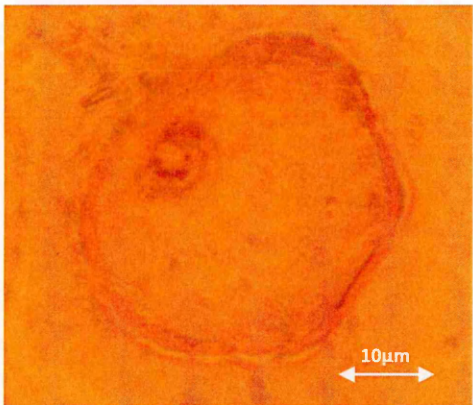


Figure 3.8 Hendra Poaceae pollen no.3 x1000, phase contrast

iii) Croft Pascoe large Poaceae pollen

Four large Poaceae grains were selected from the 77 cm and 85 cm samples of the Croft Pascoe (CPAI) core. Their details are shown in Table 3.3 below. The generally poor state of preservation of these pollen grains made secure identification difficult. Allowing for the silicone oil mounting, grains 1 and 2 fall into the *Cerealia*-type of Küster with both having an annulus diameter more than twice the pore diameter (Fig. 3.9). The larger grains, 3 and 4, have an annulus diameter that is just less than double the pore diameter and the outer

annulus boundary did not appear distinct. They may therefore fall into the category of *Glyceria*-type (Fig. 3.10).

Table 3.3 Structural details of the large Poaceae pollen from the Croft Pascoe (CPA1) core.
(No surface ornamentation was visible under phase contrast.)

No.	depth/ cm	mean diam/ μm	pore diam/ μm	annulus		exine/ μm	notes
				diam/ μm	thick/ μm		
1	77	33	2.5	8 distinct	-	-	
2	85	36	5	10 distinct	-	-	Fig. 3.9
3	85	40	6	10 diffuse	-	2	Fig 3.10
4	85	40 (47x33)	4	7 diffuse	-	2	Fig. 3.10

Using the criteria of Andersen (1979) the smaller grains (1 and 2) fall into the *Hordeum* group and grain no. 3 into the *Avena-Triticum* group. Grain no. 4 does not fall into either category but the poor preservation of this specimen may have resulted in the imprecise measurements of pore and annulus dimensions.

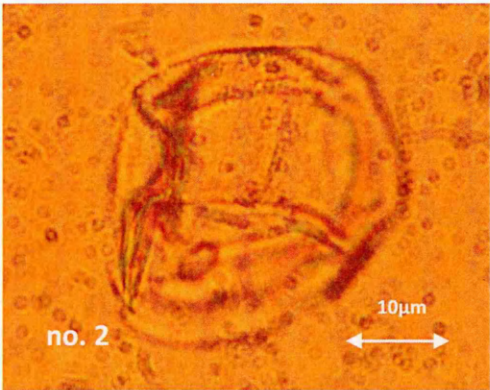


Figure 3.9 Croft Pascoe large Poaceae pollen no. 2 from 85 cm.

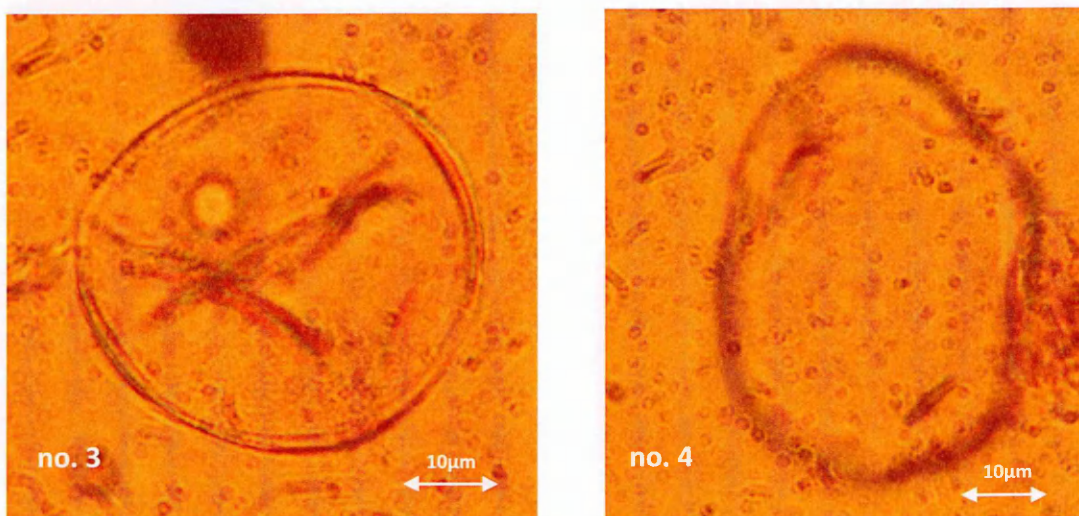


Figure 3.10 Croft Pascoe large Poaceae pollen nos. 3 and 4 from 85 cm

In summary the identifications of the small sample of large Poaceae grains from the Croft Pascoe core are more ambiguous than those from the other sites. There is still significant evidence for these pollen grains being of cultivated cereal origin, particularly of the *Hordeum* genus. There appears to be an overlap of the larger grains with genus *Glyceria* pollen, however, but their large mean diameters reduces the likelihood of their belonging to this category.

iv) Conclusions

The principal means used to differentiate these large Poaceae pollen grains has been their dimensions. The wide size variations of mean pollen size, pore diameter and annulus diameter of the Poaceae indicated by Beug (2004) and the size variations that result from different preparation techniques (e.g. Moore *et al.*, 1991) reduce the reliability of this method. In particular, the overlap of cereal pollen with the pollen of wild grasses means that no cereal grain identification can be considered completely secure. There is good evidence that most of the grains studied in detail here are derived from cultivated cereals, however, particularly those from the younger deposits of Erisey Barton and Hendra (60 cm). The identifications of those from the lower levels of the Hendra core and from Croft Pascoe are less secure and therefore have to be considered more carefully within their palynological context and taking account of the archaeological evidence.

It is also important to consider how representative of all the large Poaceae grains identified in the course of this investigation is the small sample studied in detail here. The selection of the grains was somewhat opportunistic as they had to be relocated on slides already counted. Those where location information had been included on the count sheet and slides in which large numbers of 'cereal' grains had been recorded were reviewed. There may be a bias associated with the first method as the inclusion of location information may have been encouraged by the levels of confidence with which they were identified. No bias should be present in the second method and overall it would be reasonable to assume that the selection process was very close to random.

3.3.4 Other critical pollen identifications

i) *Pinus* sp. and *Abies* sp.

Pinus pollen appears throughout the diagrams from all three sites in this study and *Abies* pollen is present in the most recently deposited sediments only. The pollen of these two

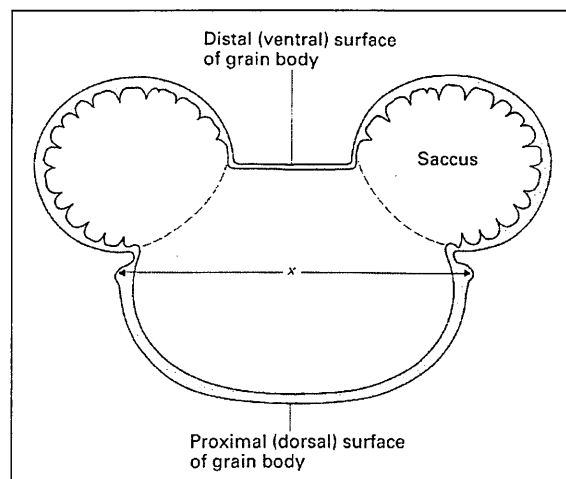


Figure 3.11 Diagram of saccate pollen grain showing constricted attachment of sacci and grain body measurement 'x' (from Moore *et al.* 1991)

taxa can be distinguished from other saccate pollen by the constriction of the sacci at the point of attachment to the body of the grain (Moore *et al.*, 1991). Figure 3.11 above shows this distinguishing feature.

The principal distinguishing feature of *Pinus* and *Abies* pollen is the comparative dimension 'x'. *Pinus* is in the size range of approximately 40-60 μm and *Abies* in the approximate range of 70-100 μm . In addition *Pinus* pollen sometimes has marginal crests under the sacchi as in Figure 3.11 (Moore et al., 1991). Figure 3.12 below shows *Pinus* and *Abies* pollen from the Lizard peninsula.

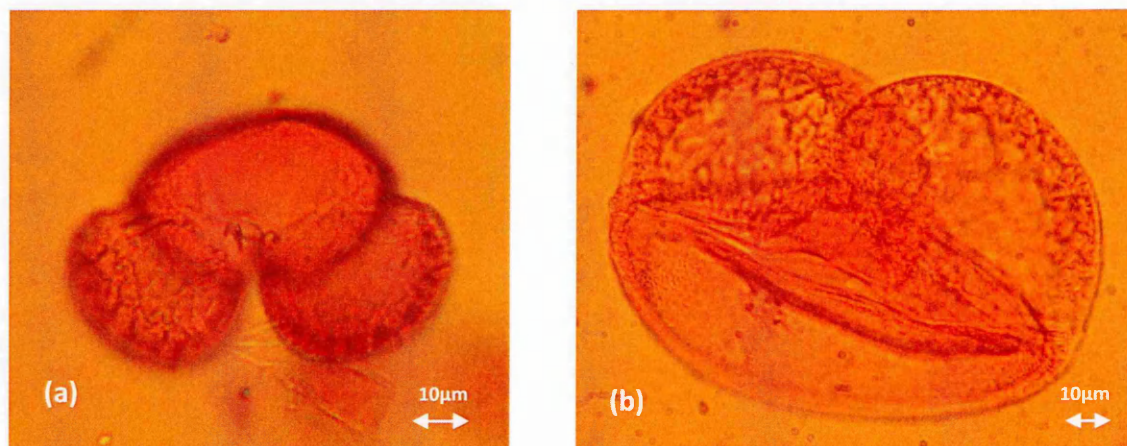


Figure 3.12 Saccate pollen from the Lizard peninsula. (a) *Pinus* sp. HEN1 10 cm x = 45 μm
(b) *Abies* sp. EBA2 30 cm x = 90 μm

ii) *Plantago* spp.

Plantago spp. pollen was initially classified as *P. lanceolata* type, *P. major* and *P. coronopus* with poorly preserved grains classified as *Plantago* undiff. Because of the large number of undifferentiated grains, however, a decision was made to use only two classifications, *P. coronopus* which is very distinctive with *Plantago* undiff. used for the remaining *Plantago* grains (Fig. 3.13).

When better preserved *Plantago* pollen was encountered during the analysis of the Erisey Barton sediments towards the end of the data collection process *P. lanceolata*, *P. major* and *P. media* pollen were more readily distinguished. It became evident that most of the *Plantago* pollen that had been classified as *Plantago* undiff. were probably *P. lanceolata*. As a result of this observation the *Plantago* undiff. curve on the pollen diagrams is being treated as *Plantago lanceolata* (type) for diagram interpretation purposes.

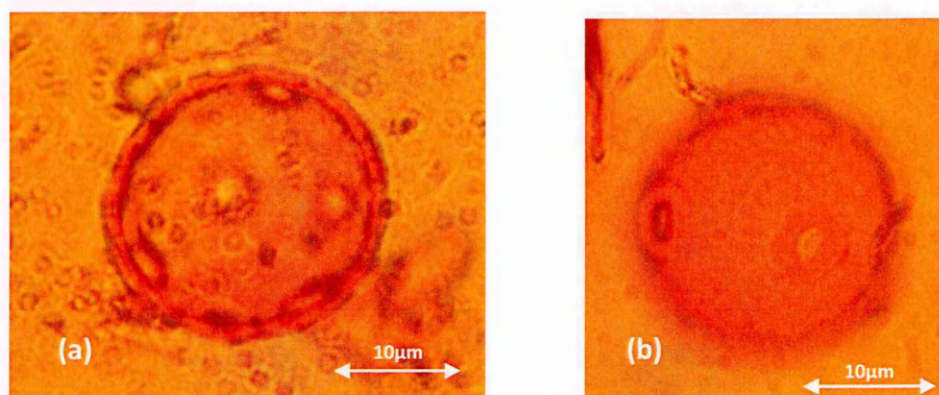


Figure 3.13 *Plantago* type pollen from EBA2 (a) 22 μm with '8-14 ringed, raised pores with plugs' identified as probably *P. lanceolata* but recorded as *Plantago* undiff. (b) 20 μm , with 'six irregular placed well ringed and raised pores appearing in focus in pairs' identified as *P. coronopus* (Andrew, 1984).

3.4 Charcoal fragments

The role of fire in producing ecosystem change is well documented (e.g. Wein & MacLean, 1983) and the intentional manipulation of biomass by prehistoric people is frequently cited (e.g. Simmons *et al.*, 1981). The value of carbon fragment analysis in identifying past forest fires was established by Clark (1988a). He compared charcoal analysis from varved lake sediments in northwestern Minnesota to red pine tree-ring fire scarring and found a very good correspondence. Since the work of Clark (e.g. 1988a, 1988b) sedimentary charcoal records are regularly collected alongside palynological data (e.g. Ali *et al.*, 2009; Waller & Grant, 2012). Microscopic charcoal fragments are deposited not only within lake sediments but also peat bogs and other sedimentary sites. The key processes involved in the interpretation of the distribution of these charcoal fragments is their production, taphonomy, dispersal and deposition. These are discussed in Patterson *et al.* (1987) and Clark (1988b).

Charcoal fragments are produced by the incomplete combustion of plant tissues, particularly wood. In the northern hemisphere softwoods are the most likely to be involved in forest fires as hardwood forests are much more fire resistant. Ure (1824) calculated that after burning, about 20% of the wood will become charcoal (e.g. 16.5% of Scots Pine, 22.7% of

Oak). The remainder generates the combustible gases carbon monoxide and methane. The more vigorous the fires the finer the charcoal particles produced (Schaefer, 1974). Burning peat can also produce charcoal, a process frequently resulting from the burning of heather during heathland management (Gimingham, 1975) or as a result of arson.

The primary agents of dispersal of the charcoal are wind and water. Aeolian transport moves the smaller particles further than the heavier particles and the total distances moved may be heavily influenced by convection currents in large forest fires. Much of the charcoal produced in fires is moved hydrologically (Rummery, 1983), in many cases more than is moved by the wind (Clarke, 1983). This may be because burning increases the rate of runoff (Hibbert, 1967) but Clark (1988b) believes that sheet wash of pollen and charcoal has been overemphasised. Patterson *et al.* (1987), assuming that charcoal particles are dispersed in a similar manner to pollen, has produced a theoretical model showing the differential distribution of different sized particles (Fig. 3.14). Clark (1988b) has refined this, taking into account the height of the convection column, suggesting that with a 10 m column charcoal particles of about 200 μm diameter are deposited about 50 m from the source of production whilst those of a diameter in the region of 20 μm between about 50 and 100 m distant. With larger fires and hence higher convection columns these distances can extend to many kilometres. Particles of about 5-10 μm , the size most frequently encountered on pollen slides, may be transported tens to hundreds of kilometres from their site of production. Wind would have the effect of exaggerating the dispersal pattern shown in Figure 3.14 in the direction of the prevailing winds adding a further dimension to the distribution pattern. Consequently the reconstruction of the intensity, size and distance of the fire from the deposition site are highly problematic. Clark (1988b) suggests that even a 1 cm interval sampling is unlikely to resolve individual fires unless the intervals between them are greater than 50 years. He also argues that the poor spatial and temporal resolution of pollen slide microcharcoal analysis has to be stressed and that 'thin section' (macroscopic) preparations of sediments in which no sieving is involved produce charcoal diagrams that most nearly approximate to known fire profiles.

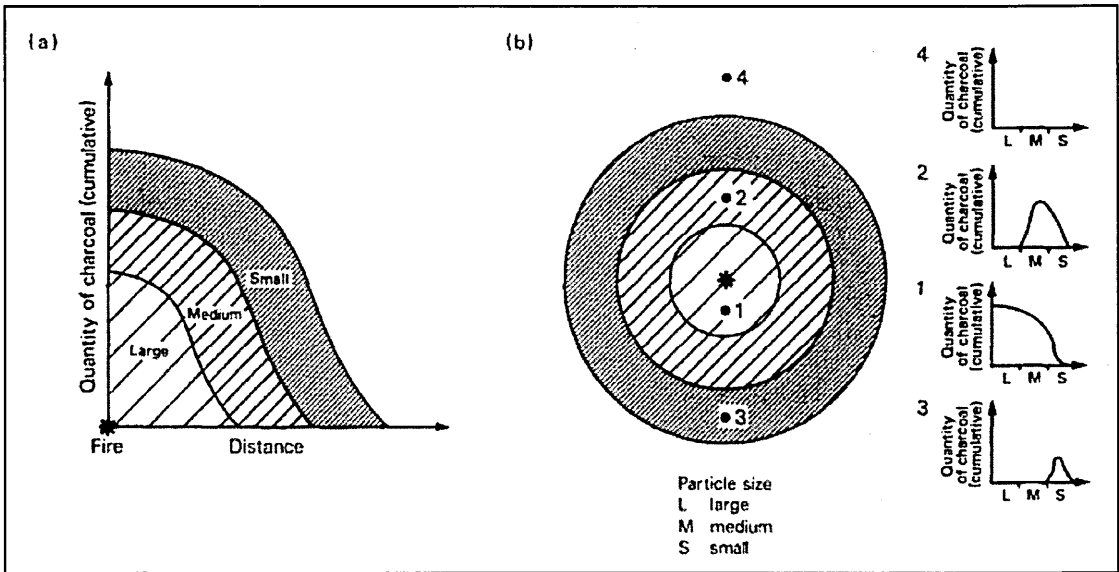


Figure 3.14 Diagrams indicating the size distribution of charcoal particle deposition after a fire. (a) Theoretical graph showing the accumulation of large, medium and small particles at increasing distances from the fire. (b) Map and graphs showing theoretical charcoal distribution in the absence of wind (from Patterson *et al.*, 1987).

Varying approaches to estimating charcoal concentrations from both pollen slides and thin section have been developed in recent years, loosely described as by area, volume or number. These are described and evaluated by Ali *et al.* (2009) who come to the conclusion that the three different proxies provide comparable fire history interpretations provided appropriate locally defined thresholds are used. In the current study pollen slide charcoal has been counted due to time constraints and the limited nature of the questions to be asked of the charcoal data. Particles $<10\text{ }\mu\text{m}$ were not counted in view of their ubiquitous nature in the atmosphere, and the limitations to the interpretation of microcharcoal diagrams pointed out by Clark (1988b) will be closely adhered to.

3.4.1 Counting charcoal fragments

Charcoal fragments were identified by their uniformly black and fractured appearance with care being taken not to include charred quartz particles or darkened cellulosic debris. Fragments of two size categories, $10\text{--}50\text{ }\mu\text{m}$ and $>50\text{ }\mu\text{m}$, were counted at approximately 5 cm intervals. The longest dimension was used to categorise the fragments but those $>50\text{ }\mu\text{m}$ in length but $<10\text{ }\mu\text{m}$ in width were placed into the smaller category. Three scans of up to

three different slides at each level were counted for both 10-50 µm and >50 µm fragments. These data were then used to estimate the number of fragments on one slide (30 scans). Using the total number of exotic *Lycopodium* spores introduced ('X' for the *Lycopodium* tablet batch) the average exotic spore count per slide and the dry mass of sediment prepared, the average mass of sediment per slide was calculated. This enabled the number of fragments per gram of sediment to be estimated. These data are displayed as three categories, occasional/frequent/abundant. Charcoal count and calculation sheets are included in Appendix I.

3.5 Pollen concentrations

The use of percentage pollen diagrams has the inherent problem of reciprocity in which the representation of each taxa is related to the percentages of all the other taxa in the total sum. Absolute pollen frequencies based upon the exotic pollen count, *Lycopodium* in this investigation, have the potential to overcome this as the value for each taxa is independent. The 'pollen influx' for example uses the number of grains accumulated per unit area of sediment surface per unit of time (grains cm⁻² yr⁻¹) and is based on accumulation rates. These require either annually laminated sediments or ¹⁴C dates at regular intervals for their calculation. Neither of these was available at the three sites investigated here. 'Pollen concentration' is a measure of the number of grains per unit of volume, or wet or dry mass of sediment. The concentration of pollen per gram of dry sediment for each sample counted in this study was calculated according to the method described by Stockmarr (1971) and Birks and Birks (1980, pp.206-208). The total number of *Lycopodium* spores introduced ('X' as above), the number of pollen grains and the number of *Lycopodium* spores counted per sample, and the dry mass of the sample were used in the following formula:

$$\text{no. of pollen grains g}^{-1} = \frac{\text{X (no. of pollen grains counted / dry mass of sample)}}{\text{no. of } Lycopodium \text{ spores counted}}$$

These pollen concentration data show large fluctuations between adjacent samples (see Figs 4.5, 4.9 and 4.13) due most probably to significant variations in the accumulation rate over

time. The use of absolute pollen values may therefore contribute to the interpretation of the pollen data. They give an indication of accumulation rates, pollen production and pollen preservation although it is difficult to distinguish between the contribution of these three variables to the pollen concentration data.

3.6 Macrofossils

Macrofossil is the term used to describe any plant or animal remains preserved in sediments that may be seen and potentially identified with the naked eye (Birks and Birks, 1980, p.66). In practice a binocular microscope is usually required for their identification and occasionally a high powered microscope or even transmission and scanning electron microscopy. The plant remains encountered are most usually fruits, seeds and megaspores although larger fragments of leaves or wood are sometimes identifiable. Larger pieces of plants may also be preserved such as fragments of moss plants or moss sporangia.

Macrofossil remains have some useful attributes in palaeoecological studies not enjoyed by fossil pollen. They are very often identifiable to species level so refining the ecological information they may provide, and since their relatively large size prevents them from being transported far from their point of production they may be confidently used to reconstruct a community. They also enable plants whose pollen may not usually be preserved, such as *Juncus* spp., to be identified. Their limited capacity to travel far from their origin, however, means that the vegetation they represent may be very local and the possible effects of currents concentrating them means that it is difficult to relate the frequency of the macrofossils to the frequency of the parent plants. They also require quite large amounts of sediment, Birks and Birks (1980) suggest a minimum of 100 cm³. This requires large diameter cores or monoliths, neither of which may be readily available.

As with all fossil assemblages, the interpretation of macrofossil evidence requires a lot of different factors to be taken into consideration. The rate of production of macrofossil seeds or fruits will have a bearing on their frequency as will their germination rate and palatability, as seeds that have germinated or been eaten will not be preserved. The size of the

macrofossil will affect the distance it travels and the distance from the parent plant will affect the frequency. Also, as with pollen, differential rates of oxidation will affect frequency of macrofossils differentially. In contrast to the many manuals and keys available for pollen and spore identification there are very few available for macrofossil identification. Those that do exist, e.g. Beijerinck (1947) and Brecht (1941), are not readily available and contain no keys. As with any type of fossil analysis, however, difficulties and limitations are inevitable and interpretations have to take these into account.

3.6.1 *Methodology for macrofossil analysis of the Hendra cores*

The HEN3a and HEN3b cores gathered from the deepest part of the Hendra mire were analysed for macrofossils using the method described by Charles Turner (6.04.12, pers. com.) and Birks and Birks (1980, pp.67-69). For the 10 cm HEN3a core this involved the removal of 50 cm³ of sediment covering 5 cm of the core at approximately 10 cm intervals. The sediment was then washed through three sieves of progressively smaller mesh size, 2.0 mm/ 71 µm/ 25 µm for the first samples and 1.7 mm/ 85 µm/ 25 µm for those sampled subsequently. Material collected in the sieves was then suspended in water and plant and animal macrofossils identified and counted using a binocular microscope with zoom magnification from x7 to x25. The same procedure was carried out for the 5 cm diameter HEN3b core but only 30 cm³ of sediment was removed at each of the levels sampled. The results were tabulated using a subjective scale of frequency. Drawings of six of the macrofossil types found in the HEN3 cores are shown in Figure 3.15.

3.7 ¹⁴C dating

Radiocarbon dating was developed in the 1950s by Willard Libby (Walker, 2005, p.17) and has since become one of the most widely used radiometric dating techniques. It depends

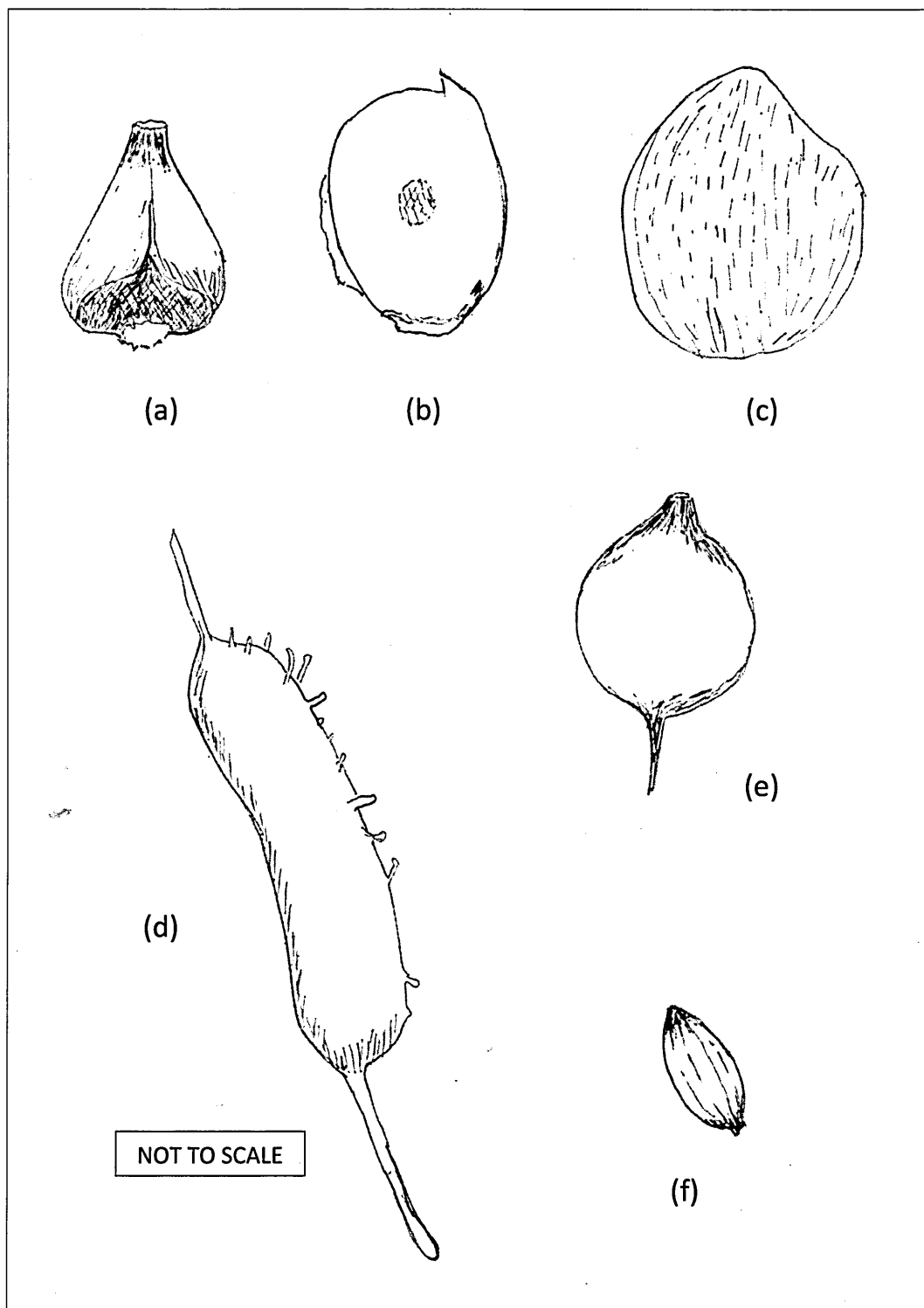


Figure 3.15 Macrofossil types found in the HEN3 cores.

- (a) Fruit of *Carex* sp. triagonalous length 2 mm (b) Seed of *Potamogeton* sp. length 3 mm
(c) Achene of *Ranunculus* sp. length 2.5 mm (d) Seed of *Zanichellia* sp. main body length 4 mm
(e) Fruit of *Carex* sp. biconvex (flat) total length 2 mm (f) Seed of *Juncus* sp. length 0.8 mm

upon the natural production of the rare carbon isotope ^{14}C in the upper atmosphere that decays over time to the stable form of nitrogen, ^{14}N , by the emission of a beta (β) particle. Plants and animals take in ^{14}C in the proportion in which it exists in the atmosphere but on their death the ^{14}C decays to ^{14}N . As a result the ratio of ^{14}C to the stable isotope ^{12}C changes over time.

^{14}C has a half life of 5 730 years which restricts the upper age limit of the technique to about 45 000 years. Modern techniques such as isotope enrichment and various forms of pre-treatment have extended this upper limit to as much as 60 000 years (Walker, 2005, p.23).

The precision of ^{14}C dating rests upon a number of assumptions one of which is that the $^{14}\text{C}/^{12}\text{C}$ in the global carbon reservoir has remained largely constant over time. In the 1970s it became clear that radiocarbon ages were invariably younger than dendrochronological ages (e.g. Renfrew, 1973) and this has been attributed to changes in the $^{14}\text{C}/^{12}\text{C}$ ratio over time. Calibration techniques have now been developed that convert 'radiocarbon years' into 'calendar years'. These were initially based on dendrochronological records from around the world which extended back to 12.4 calibrated kyr BP (INTCAL98 calibration curve). These have now been extended using marine records, in particular corals and foraminifera, with site specific marine reservoir correction, required due to the decay of ^{14}C in marine reservoirs. This has enabled the INTCAL04 calibration curve to be extended back to 26 cal kyr BP (Reimer *et al.*, 2004). Most recently refinement of these data has enabled this to be extended back even further to 50 cal kyr BP producing the INTCAL09 calibration curve (Reimer *et al.*, 2009).

There are two basic methods for obtaining radiocarbon dates, beta counting (standard radiometric dating) and accelerator mass spectrometry (AMS). Beta counting measures ^{14}C activity by detecting β emission over time. It requires at least 1-2 g of carbon which in this study translates to about 60 g of sediment, and takes days or even weeks to complete. In the 1980s a method was developed in which particle accelerators were used to directly measure the ratio of ^{14}C to the stable isotopes ^{12}C and ^{13}C . This method requires far less carbon, as little as 1 mg, and takes hours rather than days or week to complete. Initially the

dates were not as precise as those produced by β counting but refinement of the process has enabled AMS dating to match or exceed these levels of precision (Walker, 2005, p.23).

A perennial problem with ^{14}C dating is the need to obtain material that is contemporaneous with surrounding material that is to be dated and has no younger or older carbon mixed in with it. In the samples being investigated here this was a particular problem as there were rarely any larger items such as wood, charcoal or nutshell fragments that could be dated, so bulk material was used in nine of the 18 sample submissions. Although care was taken to remove roots, some younger root material would have been incorporated into the humified bulk material sampled. In addition there is the possibility of the downward movement of humic acids and the introduction of older carbon in the form of MgCO_3 dissolved in the water draining off the serpentine rock and carrying the sediment to the site.

A further possible source of error in the dating of these samples is the length of time the sediment cores, or 1 cm sections of them, were stored. This varied from a few weeks for the basal samples sent for standard radiometric dating, to six years for the most recently dated samples. Most of the samples were kept refrigerated at 4°C for most of the storage period but the samples from the EBA2 core and the HEN3 cores remained in a shed at ambient temperatures for five and two years respectively. Colman *et al* (1996) have drawn attention to the fact that wet bulk sediment samples stored at 4°C for several years may become contaminated with fungi or terrestrial bacteria which will incorporate some recent carbon into the contaminated sediment and so reduce the radiocarbon date. Wohlfarth *et al* (1998) demonstrated that the amount of modern ^{14}C incorporated will vary with the storage method but that some recent carbon from the atmosphere will almost certainly find its way into samples contaminated with microorganisms. Their analysis of the ^{14}C dates for 51 macrofossil samples indicated that 20 had radiocarbon dates significantly younger than expected. These errors were related to sample size, carbon content, storage method and time, and could be as large as 10%. Smaller samples and samples with low carbon content were most likely to produce anomalously younger dates. Recent correspondence with the head of the NERC Radiocarbon Facility, East Kilbride (pers com. Charlotte Bryant, 15.04.13) however, provided a more optimistic viewpoint. She felt that microbial growth on samples

stored in the dark would be unlikely to incorporate modern carbon but that hyphae might move the carbon around so affecting the ^{14}C content at a particular point in a core.

Although the sediment cores used in the current investigation were sealed in cling film and kept dark by foil wrapping, their storage in a wet condition at temperatures of above 4°C in some cases, and sample sizes as low as 0.01 mg, may have resulted in a reduction of the radiocarbon age as a result of microbial contamination. A combination of the two factors, root penetration and the possibility of microbial contamination, coupled with very small sample sizes mean that the radiocarbon dates used in this investigation have to be considered as minimum dates only. The possibility of them underestimating the ages of the sediments by up to 10% or more must be taken into account when interpreting the diagrams.

3.7.1 Collection and submission of samples for ^{14}C dating

Standard radiometric ^{14}C dating was conducted on the basal sediments of cores from all four sites. Samples of whole sediment of approximately 30 g dry weight were sent to the University of Waikato Radiocarbon Dating Laboratory in New Zealand in August 2006. Further material was requested by the laboratory a month later. The total amount of material required necessitated removing partial sections of the core of up to 9 cm in depth so the dates calculated represented an average age for these basal few centimetres (see Table 3.4). For the Hendra and the Erisey Barton sites the initial submission was taken from the first core (HEN1 and EBA1) and all or part of the additional material was taken from the second core (HEN2 and EBA2). The date generated was therefore an average date for the basal sediments of the two cores so methodologically unsound. Without an AMS date, however, the Erisey Barton basal date has been used as an approximate basal date for the EBA2 core. An AMS date for the HEN1 core was obtained later. Additional material from the Lizard Downs and Croft Pascoe sites was taken from the original core only (LDA1 and CPA1).

Three samples were sent for AMS ^{14}C dating at the $^{14}\text{CHRONO}$ laboratory, Queens University Belfast in May 2008. Sediment was removed from the centres of the HEN1 and

HEN2 cores of dry mass between 1 g and 3.1 g. A date from the base of the HEN2 core of approximately 2,000 years younger than expected, based on the standard radiometric date, raised suspicion that this gouge auger core may have been mixed with younger material during collection.

A further three samples were prepared for AMS dating in May 2009. A section of sediment of dry weight 0.165 g was removed from the HEN1 core at 99 cm. The CPA1 core proved more problematic as the sediment appeared to be penetrated by many fibrous rootlets. Removing them fragmented the samples. As a result a 0.014 g piece of what was identified as charred wood was removed at 40 cm and wood and leaf fragments of 0.01 g were removed at 61 cm. All three samples were sent for AMS dating to the ¹⁴CHRONO laboratory.

In July 2011 three more samples were sent for AMS dating at the ¹⁴CHRONO laboratories. A wood fragment and fragments of organic sediment of dry weight 0.0221 g were collected from the CPA1 core at 54 cm. Fragments of organic sediment of 0.034 g were collected from the HEN1 core at 71 cm and a leaf fragment of 0.072 g, possibly *Phragmites*, was collected from the EBA2 core at 70 cm. The date for the EBA2 leaf fragments was given as 'greater than modern' suggesting that they had been pushed down by the corer and folded into the sediment.

A further three samples were sent to the ¹⁴CHRONO laboratories in March 2012. These consisted of two samples of charcoal and bulk material with rootlets removed from 30 cm and 100 cm on the EBA2 core, and a wood fragment and bulk material from 79 cm on the HEN1 core. A final two samples were sent to the laboratory in September 2012, a seed case and bulk material of 0.034 g dry weight from 92 cm on the HEN1 core, and wood fragments of 0.15 g dry weight from 160 cm on the HEN3b core.

All the samples, and uncalibrated dates from earlier diagrams referred to in the thesis, were recalibrated using the OxCal online facility v 4.1.7 (Bronk Ramsey, 2010). The calibration dataset used for the samples is found in Reimer *et al.* (2009). Calibration graphs from the OxCal system for the three ¹⁴C dated cores can be found in Appendix IV. The details of all the samples and the uncalibrated and calibrated ¹⁴C dates are shown in Table 3.4 below.

Table 3.4 Samples sent for carbon dating with uncalibrated and calibrated date - yrs BP (and BC / AD)

DATE SENT	Lab. code	CORE	DEPTH/ cm	MATERIAL	MASS/g	uncalibrated ¹⁴ C date yrs BP	cal yrs BP (2σ range: 95.4%)	calibrated yrs BP (BC / AD)
28/08/06	Wk19884	HEN1/2	118-123 113-120	organic sediment	21.2+13.9	6709±98	7740-7420	7580±160 (5630 BC)
	Wk19885	EBA1/2	117-126 119-125	organic sediment	26.1+18.1	810±136	979-537	758±221 (1192 AD)
	Wk19886	CPA1	78-87	organic sediment	25.6+23.4	3746±76	4406-3897	4152±254 (2202 BC)
	Wk19887	LDA1	65-70	organic sediment	23.7+24.1	1644±102	1820-1340	1580±240 (370 AD)
13/05/08	UBA-9710	HEN1	120	organic sediment	1.0	6554±30	7553-7424	7489±64 (5505 BC)
	UBA-9711	HEN1	85	organic sediment	2.6	2200±22	2312-2148	2230±82 (299 BC)
	UBA-9712	HEN2	125	organic sediment	3.1	5044±56*	5908-5661	5785±123 (3835 BC)
5/06/09	UBA-12422	HEN1	99	organic sediment	0.165	4513±27	5300-5050	5175±125 (3225 BC)
	UBA-12423	CPA1	61	wood/leaf fragments	0.01	2648±24	2836-2740	2788±48 (838 BC)
	UBA-12424	CPA1	40	charred wood	0.014	105±22	265-23	144±121 (1806 AD)
5/07/11	UBA-18247	CPA1	54	wood/sediment	0.022	530±24	626-512	569±57 (1381 AD)
	UBA-18248	HEN1	71	organic sediment	0.034	1313±37	1298-1176	1237±61 (713 AD)
	UBA-18249	EBA2	70	leaf fragments	0.072	-24.2*	-	-
13/03/12	UBA-20268	EBA2	30	charcoal fragments, seed, bulk material	0.03	138±21	278-8	143±135 (1807 AD)
	UBA-20269	EBA2	100	bulk material minimised for root	0.05	832±22	784-691	738±46 (1212 AD)
	UBA-20270	HEN1	79	wood fragment, bulk material	0.055	1767±40	1815-1569	1692±123 (258 AD)
13/09/12	UBA-21186	HEN1	92	seed case, bulk material	0.034	3945±45	4520-4246	4383±137 (2433 BC)
	UBA-21187	HEN3b	160	wood fragments	0.150	3637±32	4082-3861	3972±110 (2022 BC)

* rejected date (assumed contaminated with more recently deposited material, see sec. 3.4)

Chapter 4 DATA PRESENTATION AND ANALYSIS

In this chapter data from the four study sites are presented and described. Only sediment data were collected from the Lizard Downs site. Palynomorph and sediment data were collected from the remaining three sites, Erisey Barton, Croft Pascoe and Hendra. These data are presented in the form of sediment descriptions based on the Troels Smith (1955) method, percentage pollen diagrams and an additional concentration pollen diagram of the HEN2 data. Macrofossil data were collected from the Hendra site and these are presented in the form of a table of abundance of the taxa identified. An initial analysis of the palynomorph evidence has been by the identification and description of local pollen assemblage zones. The Hendra macrofossil evidence has also been divided into zones and the nature of each zone described.

4.1 Lizard Downs

After attempting to identify pollen from the Lizard Downs site at several different levels using acetolysis on its own and acetolysis/HF pollen extraction treatments, it became clear that fossil pollen and spores were very rare to the extent that no material that could be positively identified as pollen or spore was found after searching several slides from each treatment type. The only palynomorphs encountered were those of the exotic marker, *Lycopodium*. A provisional decision was made that this site was unlikely to be suitable for the purposes of this study. With a view to investigating these problems further more substantial cores were collected in May 2006 (LDA1). With a basal ^{14}C age of 1580 ± 240 cal. years BP and the investigation of further samples again finding only *Lycopodium* spores a final decision was made not to investigate this site further as part of the current study. Since the deposits apparently did not extend back to the prehistoric era they would not be able to contribute

to the elucidation of the preanthropogenic landscape, and the lack of palynomorphs meant they would not be able to inform a study of heathland development.

4.1.1 Sediment description

The sediment from the Lizard Downs site was logged as follows using the Troels Smith (1955) method (see Appendix V). The core was strf.0 and sicc.2 throughout.

0-10 cm	Th ² 4, Sh+, nig.3, elas.3
10-40 cm	Th ² 4, Sh+, nig.3, elas.2,
40-55 cm	Th ² 3, Ga1, Sh+, nig.3, elas.2
55-62 cm	Th ¹ 2, Ga2, Gs+ Sh+, nig.2, elas.1
62-70 cm	Ga3, Th ¹ 1, Gs+ Sh+, nig.2, elas.1

4.1.2 Conclusions

Lizard Downs remains a very important area to the understanding of the vegetational history of the Lizard Peninsula. It has evidence of Bronze Age settlement (Thomas, 1960, 1969; Smith, 1984b) and is currently the second largest area of heathland on the peninsula. As such it should be a high priority to find further sediments on the Downs to investigate but the drainage channel sediments studied here are unlikely to be suitable at any point along their length. The high mineral content and apparently very poor pollen preservation within these sediments may be related to the interception of the original drainage pattern of this part of the peninsula during the construction of the Predannack Airfield. This could be taken into consideration when searching for new deposits. Priority may be given to the investigation of two potential Holocene sites on Lizard and Predannack Downs identified by a project archaeologist in 2006 (Sean Taylor, 26.09.06, pers. com.).

4.2 Erisey Barton

Palynomorphs from the Erisey Barton 10 cm spot samples taken from the exploratory gauge auger core were relatively well preserved and during 2005 all the 10 cm interval spot samples of the 130 cm core were prepared in the laboratory (without HF treatment). Approximately 250 palynomorphs per level were counted and a pilot diagram produced (see Appendix VIII). The strong Ericaceae curve identified in the pilot diagram informed the decision to produce a more detailed high resolution diagram from the Russian corer sections. The EBA2 core sections were selected as the EBA1 cores had deteriorated. The basal ^{14}C age of 758 ± 221 cal. years BP (1192 AD) from the EBA cores, although it can only be treated as a minimum age, tends to confirm that the valley sediment began to develop in the Medieval period, most probably as a result of the damming of the valley for the purposes of driving a water mill.

As explained in Section 3.3.3 above the Ericaceae pollen has been separated into *Calluna vulgaris*, *Erica vagans* and Ericaceae undifferentiated. *C. vulgaris* and *E. vagans* are very distinctive grains but when identification was unsafe due to poor preservation such grains were classified as Ericaceae undifferentiated. *Plantago* spp. have been classified as *P. coronopus* which is very distinctive with *Plantago* undiff. used for the remaining *Plantago* grains. As explained in Section 3.3.4 above, the majority of grains in this group are now considered to be *P. lanceolata*.

4.2.1 Sediment description

The sediment from the Erisey Barton site was logged as follows using the Troels Smith (1955) method (see Appendix V). See Figure 4.1 for a descriptive column using these data. The core was strf.0 and sicc.2 throughout.

0-10 cm	Th ¹ 4, Sh ⁺ , nig.2, elas.2
10-30 cm	Th ¹ 3, Sh ¹ , nig.2, elas.2,

30-100 cm	Th ² , Sh2, nig.3, elas.2
100-110 cm	Sh3, Th ² 1, DI+, Ga+, nig.2, elas.1
110-115 cm	Sh2, Th ² 1, Ga1, DI+, Gs+ , nig.2, elas.1
115-120 cm	Sh2, Ga2, Th ² +, Gs+, nig.2, elas.0
120-125 cm	Ga3, Sh1, Th ² +, Gs+, nig.2, elas.0

4.2.2 Pollen analysis

A total of 24 levels were counted from the surface of the feature at 0 cm to close to the base of the feature at 120 cm. The 105 cm sample was abandoned due to the scarcity of pollen and the very poor pollen preservation that made identification, particularly of the Ericaceae, unsafe. The pollen in the 115 cm sample was similarly poorly preserved but a terrestrial pollen count of 63 was obtained before this sample was abandoned. The remaining 23 levels had a total land pollen count (TLP) (not including the abundant Cyperaceae pollen) of between 245 and 355, with an average count of 316 terrestrial pollen grains per level. The TLP count used for the Erisey Barton diagrams was lower than that for the Hendra and Croft Pascoe diagrams. This decision was taken due to the removal of Cyperaceae from the TLP and the relatively minor changes in the pollen assemblages during the approximately 1000 years during which the archive has formed. This has resulted in relatively constant percentages after the 300 palynomorph point. The total land pollen counts are set out in detail in Appendix VI. The classification of the Poaceae, Ericaceae and *Plantago* spp. pollen was as described above in section 3.3.

i) Pollen taphonomy

The pollen catchment area of what was, for at least part of its life, an elongated millpond, would have been both autochthonous and allochthonous. The stream that currently flows through the valley, and would have fed the millpond during its lifetime, flows from Croft Pascoe forest on the top of Goonhilly Downs 2.5 km to the SW, to the millpond below. So the pollen assemblage here represents the flora of the Downs and of the immediate vicinity of the feature over the last approximately 900 years. Jacobsen and Bradshaw (1981) report

the work of Andersen (1970) who suggests a 20 – 30 m pollen catchment in a closed forest canopy. The open vegetation indicated by the high herbaceous pollen count would have resulted in a slightly larger catchment and this would have been linear extending from the top of Goonhilly Downs down to and along the full length of the feature. The autochthonous element would have been greatest after the pond had become completely silted up and there was no more open water. The disappearance of the *Myriophyllum* pollen in the pollen diagram (Fig. 4.2) about 200 years ago indicates a loss of the pelagic environment and therefore provides a timescale for this. The tree pollen, particularly *Pinus*, would have a considerably larger catchment area as a result of long distance wind transport.

ii) The pollen diagram

A percentage pollen diagram has been constructed using a total land pollen (TLP) count (less Cyperaceae) as 100%. The pollen diagrams are set out in Figure 4.1, Trees, shrubs, herbs and charcoal, and Figure 4.2, Spores, remaining herbs, aquatics and indeterminate. The sediment description column uses the Troels-Smith (1955) convention (with slight modification) with a full key in Appendix V. Appendix V also provides a colour key for the pollen diagrams.

iii) Diagram zonation

The pollen diagram has been manually divided into four local pollen assemblage zones EB1, EB2, EB3 and EB4 based upon changes in the representation of key taxa.

Local pollen assemblage zone EB1 (120 cm – 100 cm):

This zone has the highest *Corylus* (type), *Calluna*, Asteraceae (Lactuceae) and *Pteridium* counts and low aquatic pollen counts. There are no >50 µm Poaceae grains and *Calluna* pollen dominates the Ericaceae pollen count. The small charcoal fragment count is moderate and similar to the count in the following zone. The large charcoal fragment count is low.

The depositional environment of zone EB1 consists of fine sand, coarser at the base, containing highly humified material with some larger plant detritus at the top.

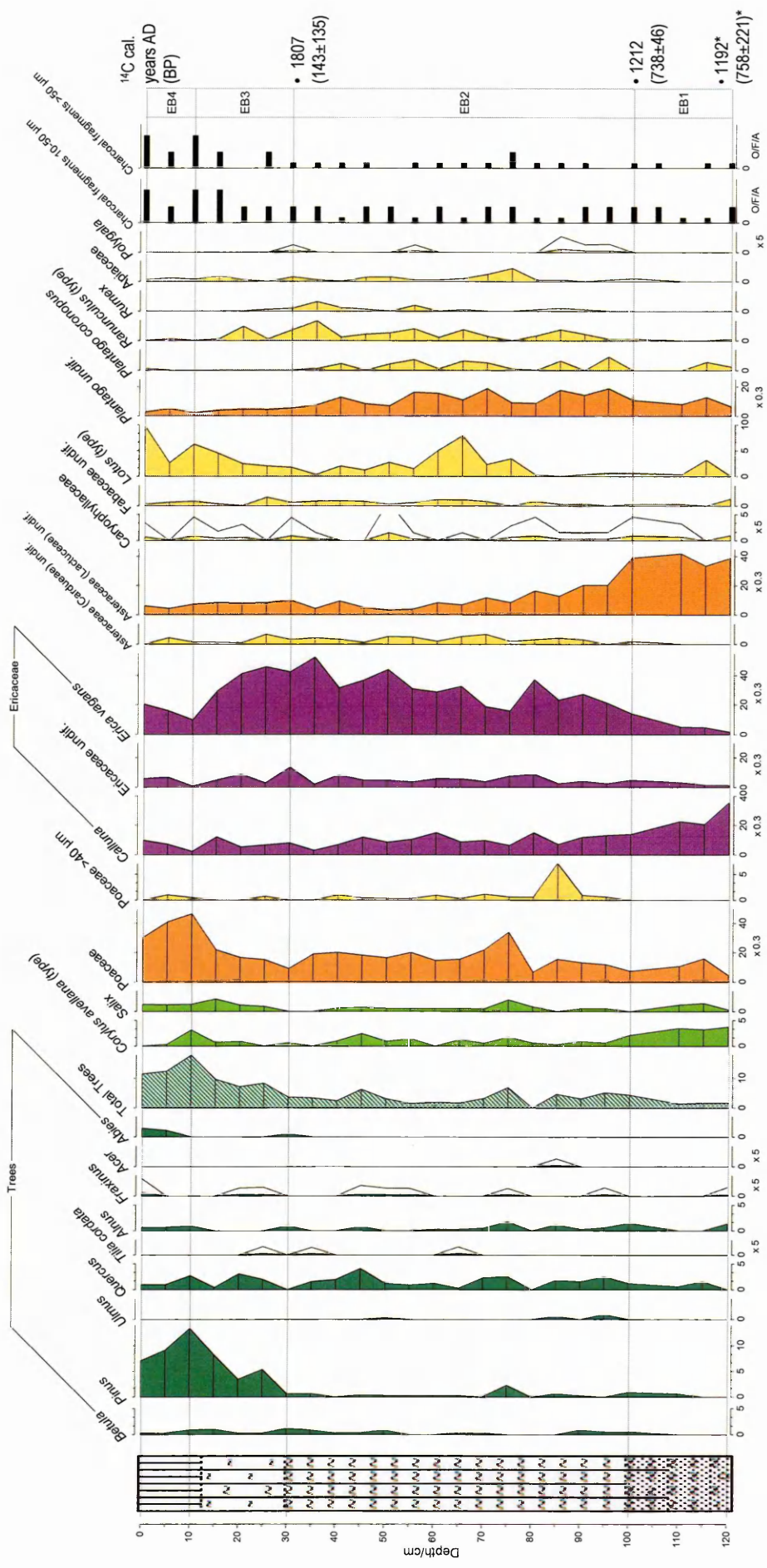


Figure 4.1 EBA2 Trees, shrubs, selected herbs and charcoal (*EBA1/EBA2)

TLP = 100%

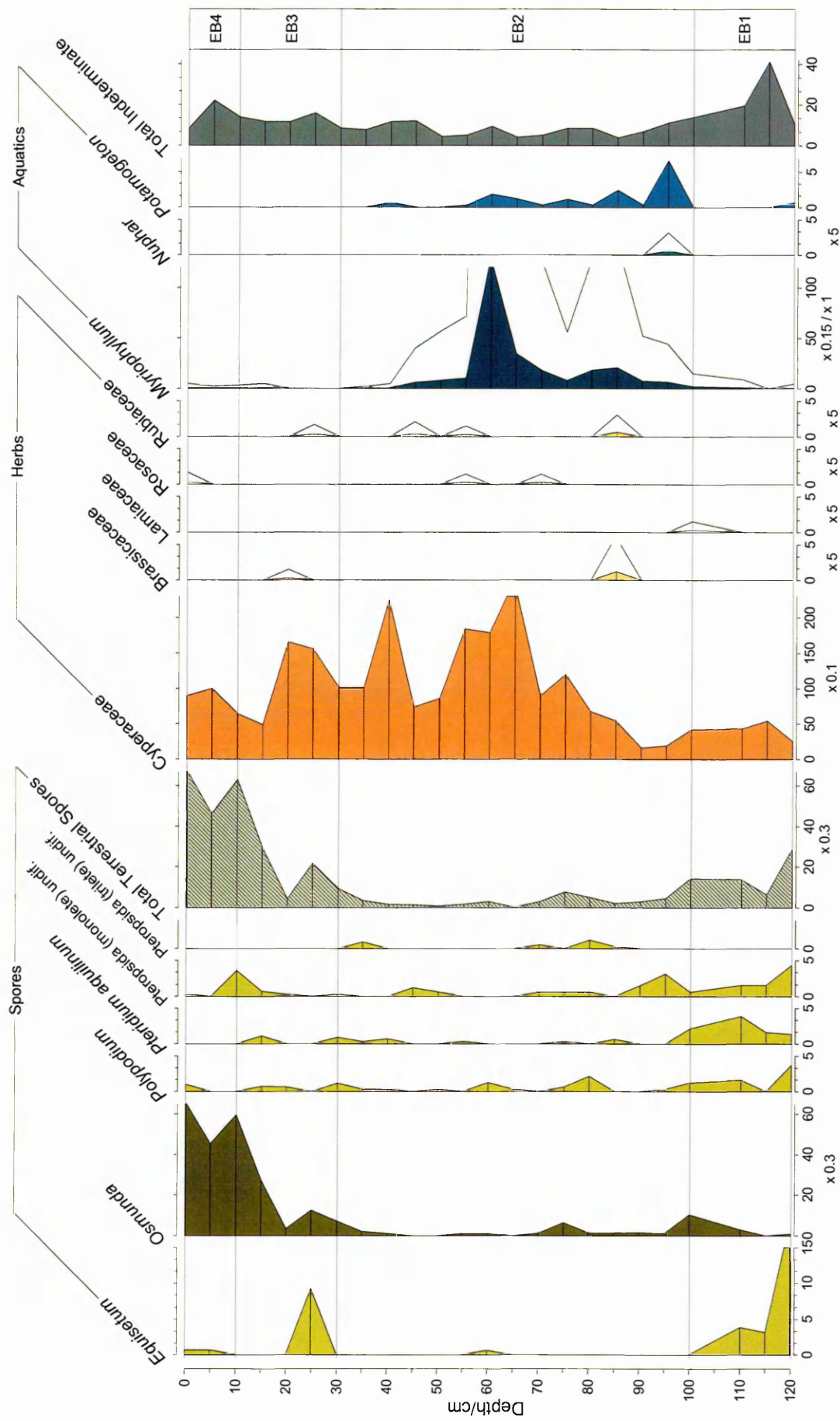


Figure 4.2 EBA2 Spores, herbs, aquatics and indeterminate

TLP = 100%

Local pollen assemblage zone EB2 (100 cm – 30 cm):

This long zone spans ca. 600 years from a ^{14}C calibrated date of 1212 ± 46 years AD to a ^{14}C calibrated date of 1807 ± 135 years AD (738 ± 46 to 143 ± 135 cal. years BP). It is characterised by a gradual increase in Poaceae pollen corresponding to a drop in Asteraceae (Lactuceae) and *Corylus* (type) pollen and a rise in *Plantago* spp. and *Erica vagans* pollen. The aquatic pollen, in particular *Myriophyllum*, increases to its maximum in the middle of this zone before dropping back. At 85 cm there is a brief but significant increase in the Poaceae >40 μm pollen, from an average of less than 1% to approximately 8% of the main pollen sum (terrestrial pollen less Cyperaceae). There are moderate and consistent occurrences of large and small charcoal fragments throughout this zone.

The depositional environment for zone EB2 is very consistent consisting of highly humified organic material and some less humified leaf and stem detritus and rootlets.

Local pollen assemblage zone EB3 (30 cm – 10 cm):

This zone is characterised by a large increase in the *Pinus* pollen, a gradual increase in the Poaceae pollen and a gradual fall of the *Erica vagans* pollen. The *Plantago* and Poaceae >40 μm curves fall back slightly and there is a steep rise in the *Osmunda* spores through the zone. There is also an increase in charcoal fragments both large and small. Aquatic pollen is very rare, comprising of a very few *Myriophyllum* grains.

The depositional environment of zone EB3 consists largely of rootlets and leaf and stem detritus with some highly humified organic material.

Local pollen assemblage zone EB4 (10 cm – 0 cm):

In this final zone there is a small drop in *Pinus* and Poaceae pollen and a slight rise in the Ericaceae. There is also an increase in *Abies* and a sharp rise in the charcoal fragments, particularly those over 50 μm .

The depositional environment over this top 10 cm consists of a dense mat of relatively un-humified monocotyledonous leaf and stem detritus penetrated by roots and rootlets.

4.3 Croft Pacoe

The 85 cm sediment core from the Croft Pascoe site (CPA1) has been one of the major subjects of this study. A basal sample of approximately 50 g of sediment using standard radiometric dating gave a ¹⁴C calibrated age of 4152±254 years BP. If this is taken as a minimum age it indicates sedimentation during the Early Bronze Age and possibly Late Neolithic so has the potential to provide valuable evidence regarding the anthropogenic impacts on the environment and the development of the heathland from a site within the modern heath in the centre of the Lizard peninsula.

4.3.1 Sediment description

The sediment description for the CPA1 core, based on the Troels-Smith (1955) techniques and convention (see Appendix V) is set out below (all strf.0) and diagrammatically in the column in Figure 4.3.

0-20 cm	Th ¹ 3, Sh1, nig.4, elas.3, sicc.2, humo.3 (<i>Phragmites</i> peat)
20-28 cm	Th ² 3, Sh1, nig.4, elas.3, sicc.2, humo.3 (<i>Phragmites</i> peat)
28-38 cm	Th ² 3, Sh1, nig.3, elas.3, sicc.2, humo.3 (<i>Phragmites</i> peat)
38-55 cm	Th ³ 2, Sh2, Ga+, nig.4, elas.3, sicc.2, humo.1 (<i>Poaceae</i> peat)
55-65 cm	Ga2, Th ³ 1, Sh1, nig 3, elas.2, sicc.2, humo.2.
65-72 cm	Th ² 1, Sh1, Gg1, Ga1, nig 3, elas.1, sicc.2, humo.4
72-85 cm	Gg2, Ga1, Th ² 1, nig.2, elas.1, sicc.2, humo.1

The plant macro remains consist of many rootlets (< 1 mm diameter) and a few aerial parts of *Poaceae* including leaf blades and sheaths. Over the upper 38 cm these appear to be *Phragmites* remains but this is less clear over the remainder of the core.

4.3.2 Pollen analysis

A total of 19 levels have been counted from 39 cm to the base of the core at 85 cm. Initially samples were counted at 5 cm intervals where possible, but where pollen concentration and preservation were poor samples immediately above or below were counted. As the pollen diagram emerged intermediate samples in areas of change were counted with a resolution of 1 cm intervals at critical points. Time constraints prevented the counting of the top 40 cm of the core. All the levels were counted to between 385 and 514 terrestrial pollen grains with an average count of 435 grains (see Appendix VI). Terrestrial spores were not included in the main sum. Poaceae, Ericaceae and *Plantago* spp. classifications are as described above in section 3.3.

i) Pollen taphonomy

The nature of the *Phragmites* peat sediment and the morphology of an apparently non-drainage feature suggest an autochthonous pollen assemblage. As described in Chapter 5 Andersen (1970) showed that within a closed forest, pollen does not travel beyond 20–30 m from its source. In the more open vegetation suggested by the high herbaceous pollen count at Croft Pascoe it may be safe to assume a larger pollen catchment area but with the majority of the herbaceous pollen representing an area within 30 m radius of the sample site. The tree pollen can be expected to travel further and so represent the tree flora of a larger area (Moore *et al.*, 1991, p.26). The structure of the landscape that produced the pollen must be speculated upon with due consideration of the problem of equifinality, originally cited by Oldfield (1970), in which a similar pollen rain will be produced from many distant plants as from a few close plants. The observed pollen assemblage results from a combination of different communities at varying distances from the sampling site.

ii) The pollen diagram

A percentage pollen diagram has been constructed using the total land pollen (TLP) count as 100%. Terrestrial spores were not included in the TLP. The pollen diagram is set out in Figure 4.3 (trees, *Corylus*, selected herbs and charcoal), Figure 4.4 (remaining shrubs and herbs, and aquatics) and Figure 4.5 (spores, indeterminate and pollen g⁻¹ dry weight). Pollen diagram colour codes appear in Appendix V.



Figure 4.3 CPA1 Trees, *Corylus*, selected herbs and charcoal

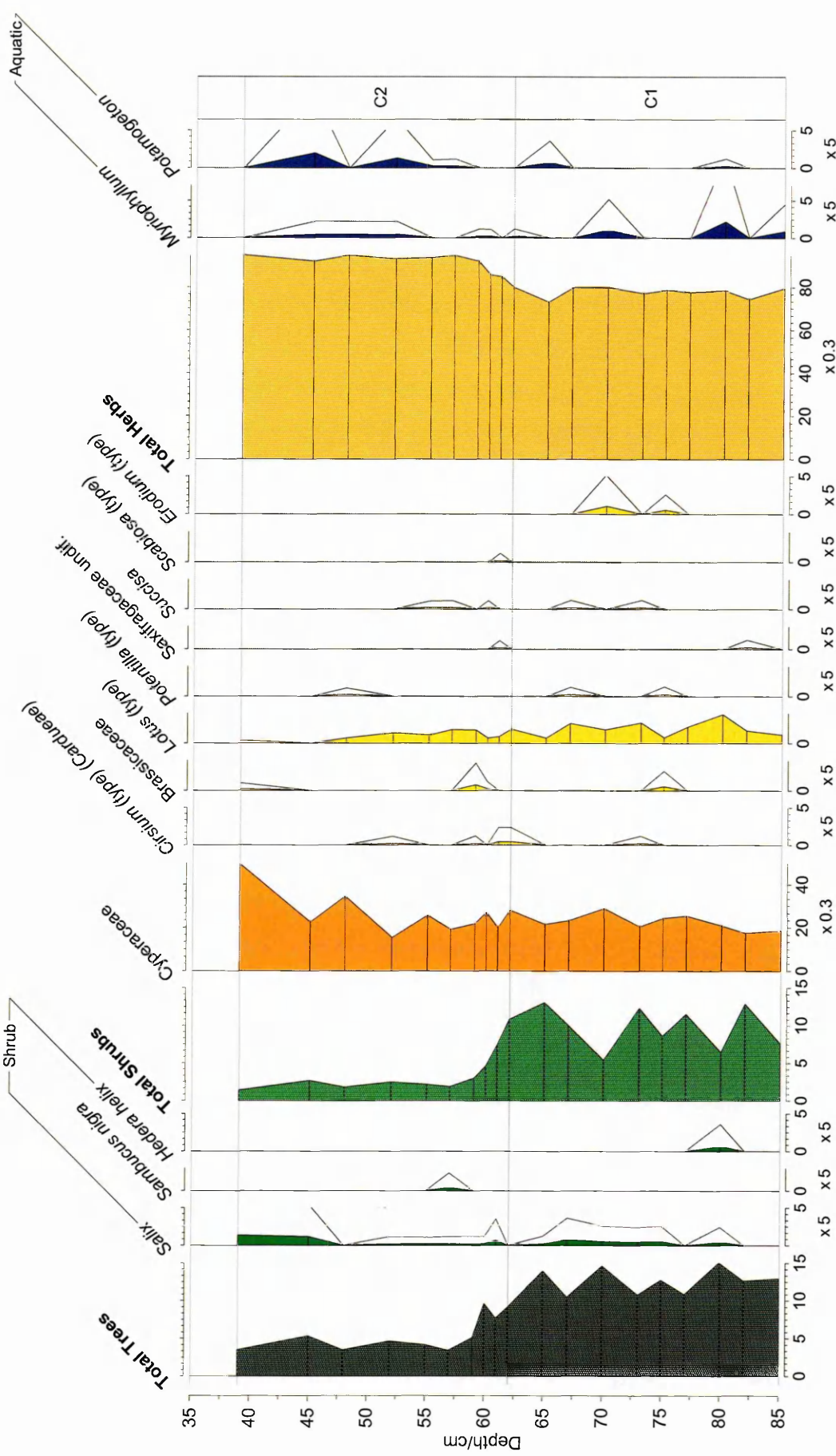


Figure 4.4 CPA1 Remaining shrubs and herbs, and aquatics

TLP = 100%

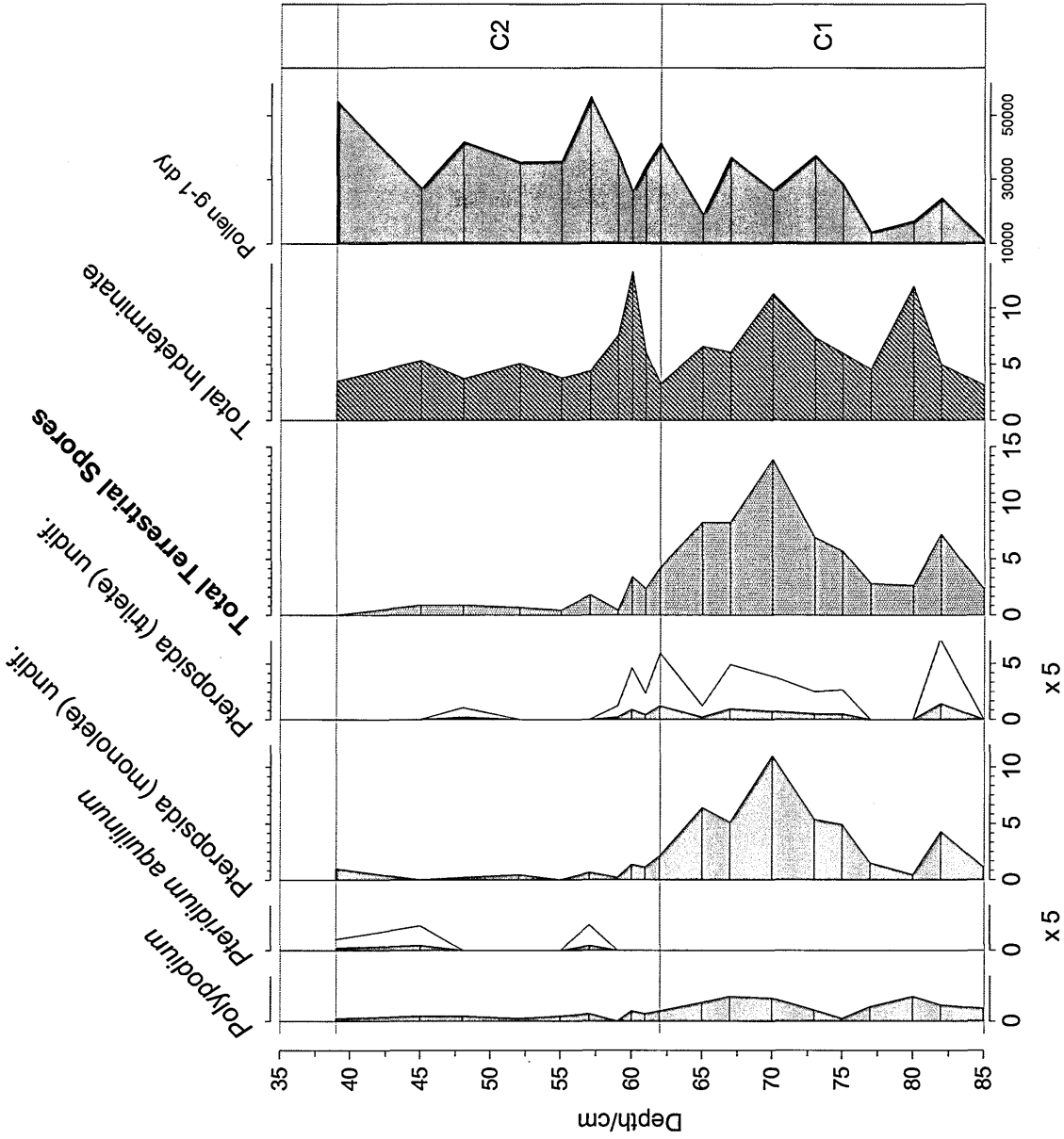


Figure 4.5 CPA1 Spores, indeterminate and pollen g⁻¹ dry weight

TLP = 100%

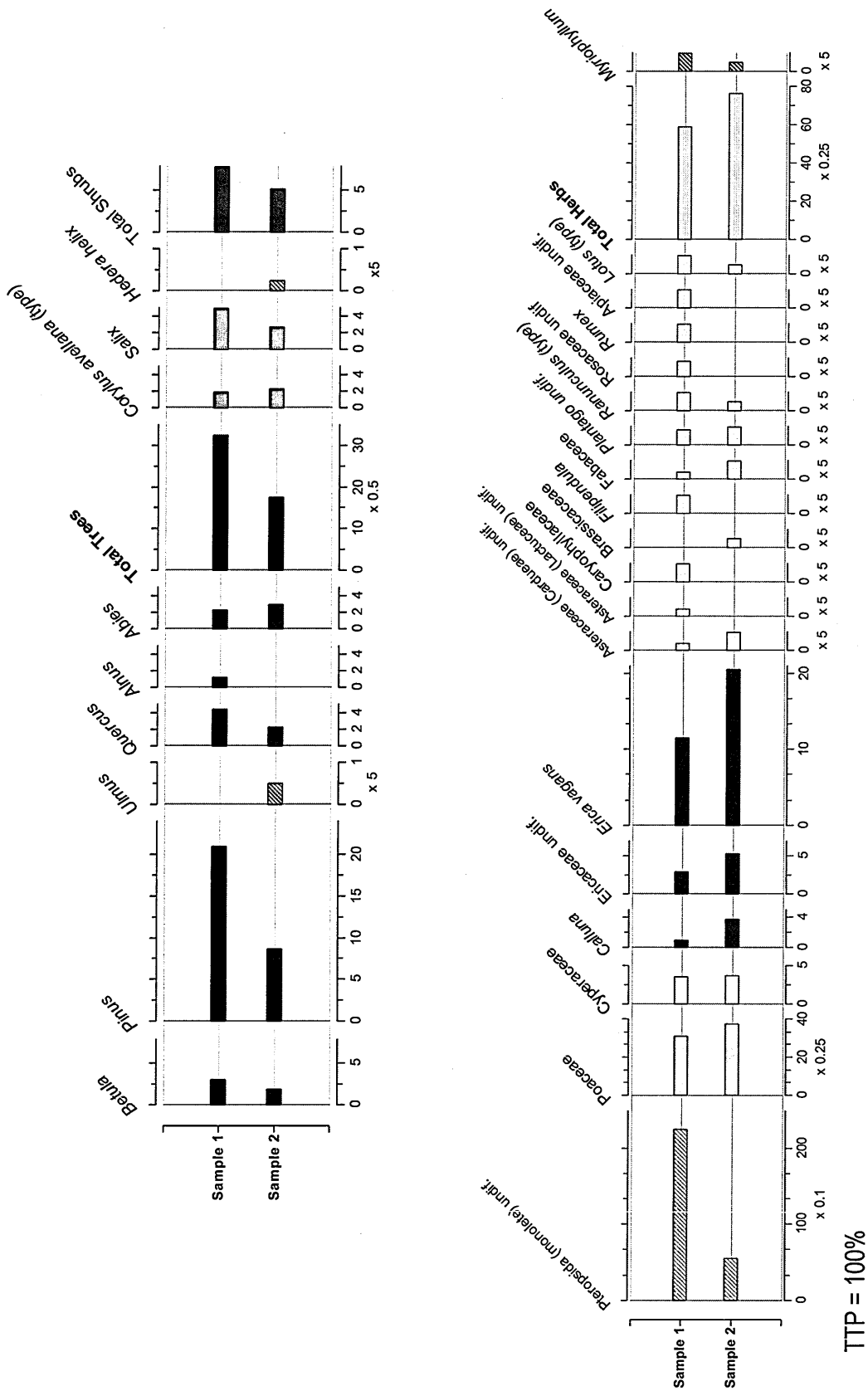


Figure 4.6 Croft Pascoe surface samples

iii) Diagram zonation

The diagram has been manually divided into two local pollen assemblage zones, zone C1: 85-62 cm and zone C2: 62-39 cm. This division has been made on the basis of the commencement of a decline in the proportion of tree and shrub pollen from ca. 25% to 8% of the total land pollen (TLP) and a synchronous rapid rise in the proportion of Ericaceae pollen from ca. 7% to 45% of TLP. These changes occur between 62 cm and 57 cm.

Local pollen assemblage Zone C1 (85 cm – 62 cm):

The ^{14}C calibrated dates for this zone are from 4152 ± 254 years BP at 85 cm to 2788 ± 48 years BP at 61 cm, a period of approximately 1,400 years. Throughout this interval the tree pollen contributes between 13 and 15% of the TLP with the principal contribution from *Quercus*, followed by *Betula* and *Alnus* and with a consistent low background representation from *Pinus*, *Ulmus*, *Tilia* and *Fraxinus*. The shrub pollen is dominated by *Corylus* (type) that fluctuates between 6% and 13% of TLP.

The herbaceous pollen is dominated by Poaceae with 30-45% and Cyperaceae with 18-26% of TLP. The remainder of the herbaceous pollen is made up from Ericaceae, Asteraceae, *Plantago* and *Ranunculus*, all less than 4% but with *Plantago* rising to 7% of TLP. Of greatest interest, however, is the appearance during the first two thirds of this section of the core of $>40 \mu\text{m}$ Poaceae grains, constituting up to 3% of TLP. The disappearance of these grains towards the end of the period coincides with a significant increase in the Pteropsida (monolete) undiff. spores.

The depositional environment of zone C1 is fine sand with some gravel, with the addition of humified material over the top 18 cm.

Local pollen assemblage Zone C2 (62 cm – 39 cm):

Zone C2 starts close to a ^{14}C calibrated date of 2788 ± 48 years BP at 61 cm but at 54 cm the ^{14}C calibrated date is 569 ± 57 years BP suggesting a hiatus at some point in the depositional record. This is reinforced by a ^{14}C calibrated date of 144 ± 121 years BP at 40 cm.

The boundary is marked by a fall in the tree and shrub pollen from 20% of TLP at 67 cm to 5% at 57 cm. The rise in Ericaceae pollen over the same interval is from 6% to 43%. The majority of the remaining herbaceous pollen taxa percentages vary little between the two zones. Four taxa appear to become scarcer following the increase in the Ericaceae however and these are the Asteraceae (Carduae), Caryophyllaceae, Chenopodiaceae and Ranunculaceae. At the top of this zone there is a small rise in *Pinus* pollen and a first appearance of the pollen of the exotic conifer *Abies*.

The depositional environment of zone C2 consists of highly humified material, sandy over the bottom 8 cm and with a higher proportion of less humified stem and leaf detritus over the top 15 cm.

iv) Surface sample pollen diagrams

Surface sample diagrams from the CPAI core site were constructed in order to inform the interpretation of the main pollen diagram. Moss polsters from around the base of the ferns in the *Phragmites* beds at the point from which the CPAI core was taken were analysed for their pollen content. The diagrams for two moss polster samples are shown in Figure 4.6. They show a total tree pollen representation of between 19 and 33% of the TLP, dominated by *Pinus* with some *Betula*, *Quercus* and *Abies* pollen and a low representation of *Alnus* and *Ulmus* pollen. The herbaceous pollen is dominated by Poaceae and *Erica vagans* with a sharp drop in Cyperaceae pollen from the 39 cm sample (the top sample from the CPAI core analysed) and a very low representation of the remaining herbaceous taxa.

The surface sample assemblage corresponds closely to the 'Tall Heath' flora described by Coombe and Frost (1956) associated with the serpentinic soils of the plateau (see Section 2.3.2). The pollen assemblage of zone C2 is very similar to that of the surface sample suggesting that 'Tall Heath' is a very stable vegetational type. The points of difference are the drop in Cyperaceae pollen from about 40% of TLP in zone C2 to about 4% in the surface sample, the drop in the *Plantago* representation and the higher *Pinus* pollen count. These changes would be consistent with a reduction of grazing in the vicinity of the site and the establishment of coniferous plantations on the peninsula over the past 100 years.

4.4 Hendra

The 120 cm sediment cores (HEN1 and HEN2) provide the longest pollen record of the four sites sampled. The location of the coring site on the mire surface is shown in Fig. 2.11. The AMS ^{14}C age for 1 g of sediment from the base of the HEN1 core is 7489 ± 62 cal. years BP. The HEN2 core was collected about 1 m west of the HEN1 core but no reliable ^{14}C date has been obtained for the base of this core. A standard radiometric date for approximately 35 g of material taken from the base of the two cores gives a ^{14}C age of 7580 ± 160 cal. years BP (see Table 3.4). Both cores were analysed for palynomorphs.

The two cores taken from the third site at the deepest part of the mire measured so far, about 50 m to the east of the HEN1 site (see Fig. 2.11), are the 10 cm diameter HEN3a, 0 – 115 cm, and the 5 cm diameter HEN3b, 100 – 180 cm. The ^{14}C age of wood fragments collected from the HEN3b core at 160 cm is 3972 ± 110 cal. yrs BP. These cores were analysed for macrofossils.

4.4.1 HEN3a and HEN3b sediment description and macrofossil analysis

i) Sediment description

The sediment descriptions for the HEN3a and HEN3b cores based on the Troels-Smith (1955) techniques and conventions (see Appendix V) appears below (all strf.0).

HEN3a

0-50 cm	Th ² 3, Dh ² 1, Ga ⁺ , nig.2, elas.2, sicc.2, humo.2
51-100 cm	Th ¹ 2, Dh ¹ 2, nig.3, elas.2, sicc.2, humo.1
100-115cm	Dh ¹ 3, Th ¹ 1, nig.3, elas.2, sicc.2, humo.1

HEN3b

100-145 cm	Th ¹ 2, Dh ¹ 2, nig.3, elas.2, sicc.2, humo.1
145-160 cm	Th ² 3, Dh ² 1, Ag ⁺ , Gs ⁺ , nig.4, elas.2, sicc.2, humo.2
160-170 cm	Th ² 2, D1 ² 1, Gs1, Ga ⁺⁺ , nig.4, elas.2, sicc.2, humo.2
170-180 cm	Th ² 2, D1 ² 1, Gg1, Gs ⁺⁺ , nig.4, , elas.2, sicc.2, humo.2

The plant material in the top 50 cm was dominated by *Phragmites* roots, stems and leaves. Below this it appeared to be *Carex* and *Juncus* fragments along with much unrecognisable material. The larger mineral particles at the base of the HEN3b core were derived from the serpentine bedrock.

ii) Macrofossil zonation

The macrofossil analysis of the two cores is set out in Tables 4.1 and 4.2. Every other 5 cm section was investigated with the intermediate samples also being investigated at 0 cm, 51 cm, 61 cm and 126 cm where there appeared to be increased changes in the macrofossil assemblage. The abundance of *Zanichellia palustris* L. seeds at 111-115 cm in the HEN3a core matches with similar abundance of these seeds at 126-130 cm in the HEN3b core. There is therefore assumed to be an approximately 20 cm overlap between these two cores with these two samples representing the same depth in the mire. This overlap of the macrofossil evidence closely matches the overlap of the depth measurements of the two cores. The charcoal fragments identified here were macroscopic in size (>1 mm).

Four zones have been identified using the macrofossil evidence, starting from the base of the HEN3b core.

Zone A. (140 cm -180 cm) HEN3b

This section of the core is characterised by high levels of moss and charcoal fragments, gravel chips and low levels of *Juncus* seeds. *Z. palustris* seeds appear towards the top of this zone.

Zone B. (90 cm – 135 cm) HEN3a - HEN3b

The most significant feature of this zone is the rise of *Zanichellia* seeds to a 'super' abundance (>200 in 50 cm³) at approximately 110 cm (HEN3a) and 125 cm (HEN3b) followed by a more rapid tailing off than their rate of build up. *Juncus* seeds now appear regularly but there is almost no evidence of charcoal. Acarine (mite) carapaces and *Potamogeton* seeds also appear in the *Zannichellia* seed rich sediment.

Table 4.1 HEN 3a Macrofossils

No data

Key: + present /++ occasional / +++ frequent / +++++ common / ++++++ abundant

depth/cm	0 – 5	6- 10	11- 15	16- 20	21- 25	26- 30	31- 35	36- 40	41- 45	46- 50	51- 55	56- 60	61- 65	66- 70	71- 75	76- 80	81- 85	86- 90	91- 95	96- 100	101- 105	106- 110	111- 115
Macrofossil																							
<i>Oenanthe crocata</i>	++	+																					
<i>Eupatorium cannabinum</i>	++ ++	++																					
<i>Carex</i> spp. (biconvex)												+	+		+		+						
<i>Carex</i> spp. (triangular)						+		+		++ +	++ +	++	+		+		+						+
<i>Juncus</i> spp.		++ ++		++ ++		++ +		+		++	++		++ +		++ ++		++ ++		++ +		++		++
<i>Potamogeton</i> spp.											+												++
<i>Zannichellia palustris</i>																			+		++		+++ +++
<i>Ranunculus</i> spp.				+		+							+						+				
Charophyte oosphere										+	++	+					++ +						+
Moss cap/ fragments	+	+		+							+										+		++ +
A								+															
<i>Pedicularis palustris</i>								+		+		+							+				
Acarines (mites)										+							+						
Insect fragments	+			+				+									++				+		
<i>Pisidium</i> sp.	++																						
Charcoal fragments	+	+				++ +				++ ++		+	++ +									+	

Zone D

Zone C

Zone B (part)

Table 4.2 HEN 3b Macrofossils

No data

Key: + present /++ occasional / +++ frequent / ++++ common / +++++ abundant

depth/cm	100-105	106-110	111-115	116-120	121-125	126-130	131-135	136-140	141-145	146-150	151-155	156-160	161-165	166-170	171-175	176-180
Macrofossil																
<i>Oenanthe crocata</i>																
<i>Eupatorium cannabinum</i>																
<i>Carex</i> spp. (biconvex)																
<i>Carex</i> spp. (triagonous)																
<i>Juncus</i> spp.	++		++		++	++	+		++							++
<i>Potamogeton</i> spp.																
<i>Zannichellia palustris</i>					++	+++ +++	++ +		++		+					
<i>Ranunculus</i> spp.	+															+
Charophyte oosphere									+							+
Moss cap/fragments	++								++		++		++ +			++ +
A																
<i>Pedicularis palustris</i>																
Acarines (mites)	+				+	+	+									++
Insect fragments	++ +		++ +													
<i>Pisidium</i> sp.																
Charcoal fragments									++ +		++ +		++ ++			

Zone B (part)

Zone A

Zone C. (45 cm – 90 cm) HEN3a

Zanichellia seeds disappear completely at the base of this zone, *Juncus* seeds become common to abundant, *Carex* seeds become common, particularly triagonal seeds, and charcoal fragments become common towards the youngest part of the zone. There is also the first regular appearance of Charophyte oospores. *Pedicularis palustris* L. seeds also occur throughout this zone.

Zone D. (0 cm – 40 cm) HEN3a

In this final zone *Juncus* seeds remain common but *Carex* seeds disappear after the bottom 10 cm. Charcoal fragments persist and moss fragments, including capsules, appear at the top of the zone. The surface 10 cm of sediment contains occasional *Oenanthe crocata* and commonly *Eupatorium cannabinum* seeds that reflect the extant flora of the site. The bivalve mollusc *Pisidium* was also found alongside live *Enchytraeid* worms.

4.4.2 HEN1 sediment description

The sediment description for the HEN1 core, also based on the Troels-Smith techniques and convention (see Appendix V), is set out below.

0-20 cm	Th ² 3, Dh ² , Sh ⁺ , nig.4, strf.0, elas.3, sicc.2, humo 3
20-42 cm	Th ² 3, Sh ¹ Ga ⁺ , nig.3, str.0, elas.3, sicc.2, humo 2
42-80 cm	Th ³ 2, Sh, As ¹ , Ga ⁺ , nig.4, str.0, elas.4, sicc.2, humo 3
80-112 cm	As ² , Th ¹ 2, Ga ⁺ , Gg ⁺ , nig.4, str.0, elas.1, sicc.2, humo 1
112-119 cm	As ³ , Th ¹ 1, nig.2, str.0, elas.1, sicc.2, humo 0
119-123 cm	As ² , Th ¹ 2, nig.3, str.0, elas.2, sicc.2, humo 0

The macro plant remains consisted of many rootless (< 1 mm diameter) and Poaceae, probably *Phragmites* leaf blades and sheaths in the top 40 cm. Rootlets and Poaceae detritus were found throughout the full length of the core. No traces of wood were found. The basal 3 cm of the core were present when the core was first collected, but had been

absorbed into a 120 cm length at the time of sampling due to shrinkage. The 20 cm, 42 cm and 80 cm boundaries were 'very gradual', the 112 cm boundary 'gradual'.

4.4.3 HEN1 pollen analysis

A total of 30 levels were counted from 10 cm to the base of the core at 120 cm. In addition two moss polster surface samples were analysed. All the sediment samples were counted to between 132 (from a small amount of material) and 442 terrestrial pollen grains with an average count of 344 grains for each sample (see Appendix VI). The spore count was not included in the main sum. The identification of the pollen of Ericaceae and *Plantago* taxa followed the same convention as described in Section 3.3.

i) Pollen taphonomy

The scarcity of aquatic pollen throughout most of the diagram indicates that there was only occasional permanent open water during the build up of sediment in the basin. (Macrofossil evidence from the HEN3 cores indicates standing water, but possibly only seasonal.) This supports the explanation (see section 2.4.1) that the sediment built up as a result of flooding episodes in which the adjacent stream overflowed into the basin, an abandoned terrace, bringing with it clay particles and organic material from the catchment area approximately 1 km to the northwest. Much of the pollen collected in the basin can therefore be considered to be of allochthonous origin having been transported by the river. This may have been responsible for the poor preservation of much of the pollen from this core. There is also the possibility of secondary deposition from eroded substrates (Moore *et al.*, 1991, p.13) which would complicate the interpretation of the pollen assemblage and also result in poor preservation. The small catchment area of the stream, however, suggests that the alluvial pollen represents a relatively small area of this region of the peninsula. Autochthonous pollen from the surrounding vegetation close to the basin would have also contributed to the pollen rain and both this local component, and the extra local alluvial component, will have been modified by the replacement of the forest by a more open environment as

indicated by the diagram. Tauber (1965) demonstrated the difference between the canopy and trunk space components and Jacobson and Bradshaw (1981) produced a model showing that for a small basin (such as the Hendra site) the canopy and rain components provide only a small proportion of the pollen rain. This relationship depends upon a closed canopy, however, so an increase in canopy and rain components might be expected should the environment become more open.

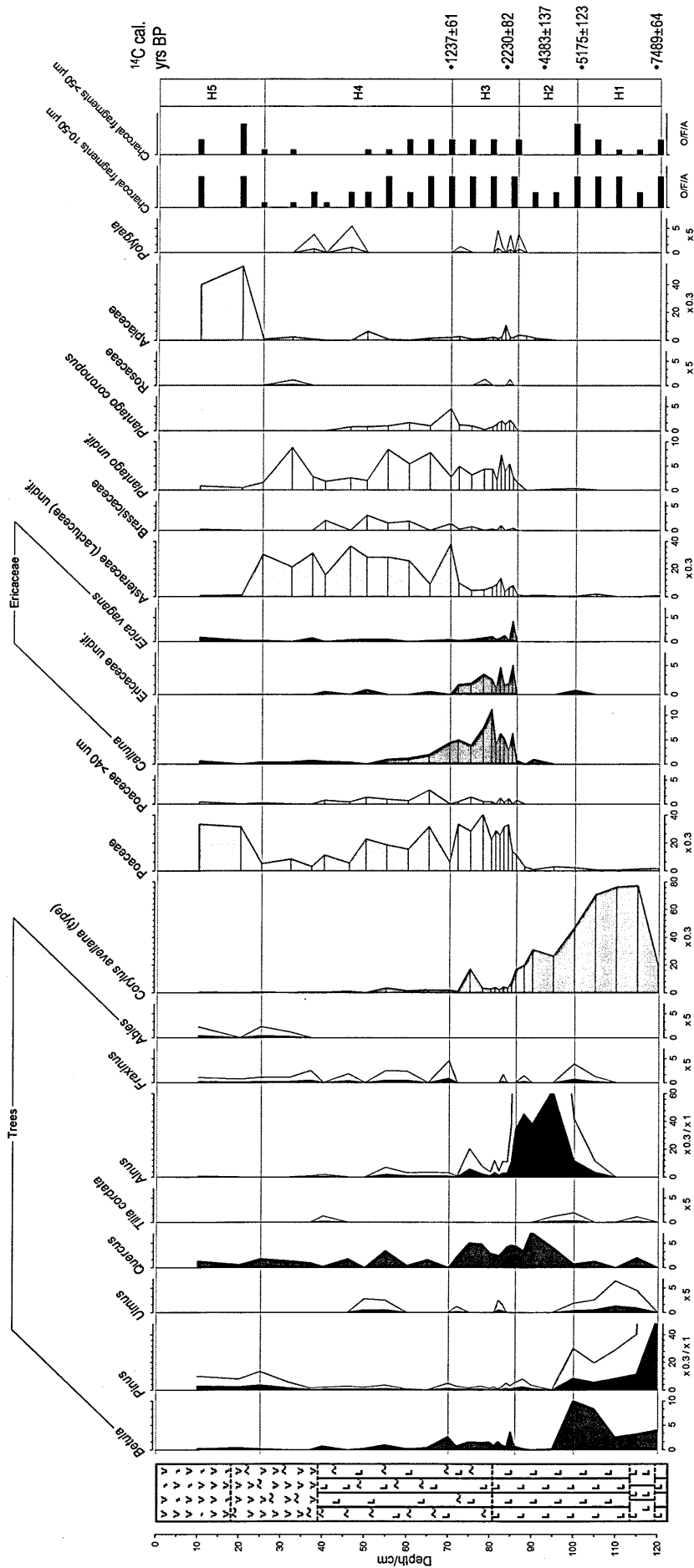
A reasonable estimate of the extent of the pollen catchment area, therefore, might be between 1 km² and 2 km² but with some more distant components, these increasing as the area became more open. This area would include what is now the southern part of Goonhilly Downs. The analysis of surface samples from the Hendra site (Fig. 4.10) in relation to the extant floral distribution of the area provides an important contribution to the establishment of the pollen taphonomy.

ii) The pollen diagram

The pollen diagram for this site is shown in Figure 4.7 (tree, *Corylus* and selected herbs), Figure 4.8 (remaining shrubs and herbs, and aquatics) and Figure 4.9 (spores, indeterminate and pollen concentration). The sediment description column uses a modified Troels-Smith (1955) convention with a full key set out in Appendix V.

iii) Diagram zonation

During the period represented by the base of the diagram the tree and shrub pollen constitute 75-90% of the total land pollen (TLP). Following this period there is an abrupt decline in the tree and shrub pollen to 10-30% of the TLP, replaced by herbaceous pollen and some cereal type (*Poaceae* >40 µm) grains. On the basis of these changes the pollen assemblage has been divided into five local pollen assemblage zones, zone H1 from 120 cm to 100 cm, zone H2 from 100 cm to 86 cm, zone H3 from 86 cm to 70 cm, zone H4 from 70 cm to 32 cm and zone H5 from 32 cm to the top of the diagram.



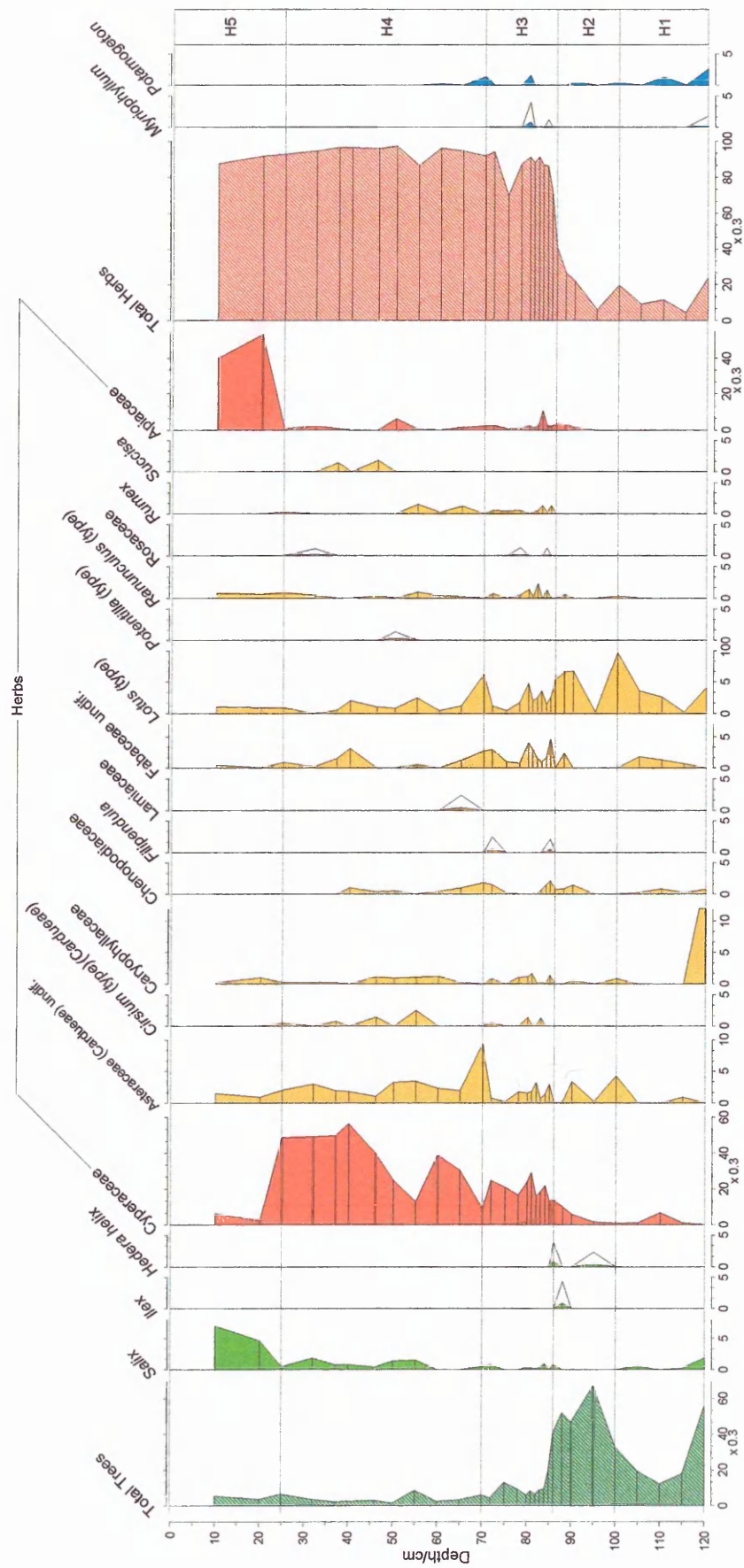


Figure 4.8 HEN1 Remaining shrubs and herbs, and aqautics

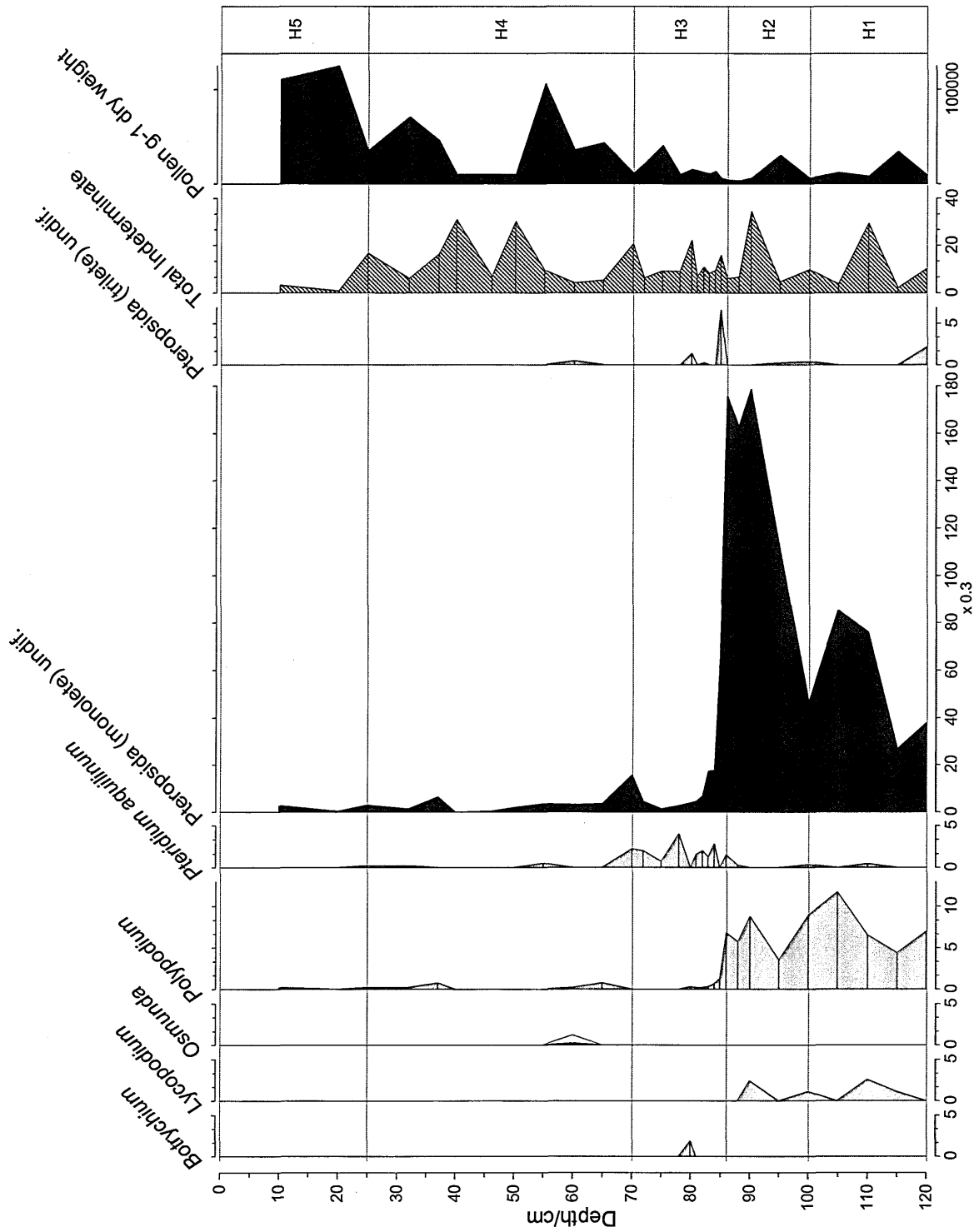


Figure 4.9 HEN1 Spores, indeterminate and pollen g⁻¹ dry weight

TLP = 100%

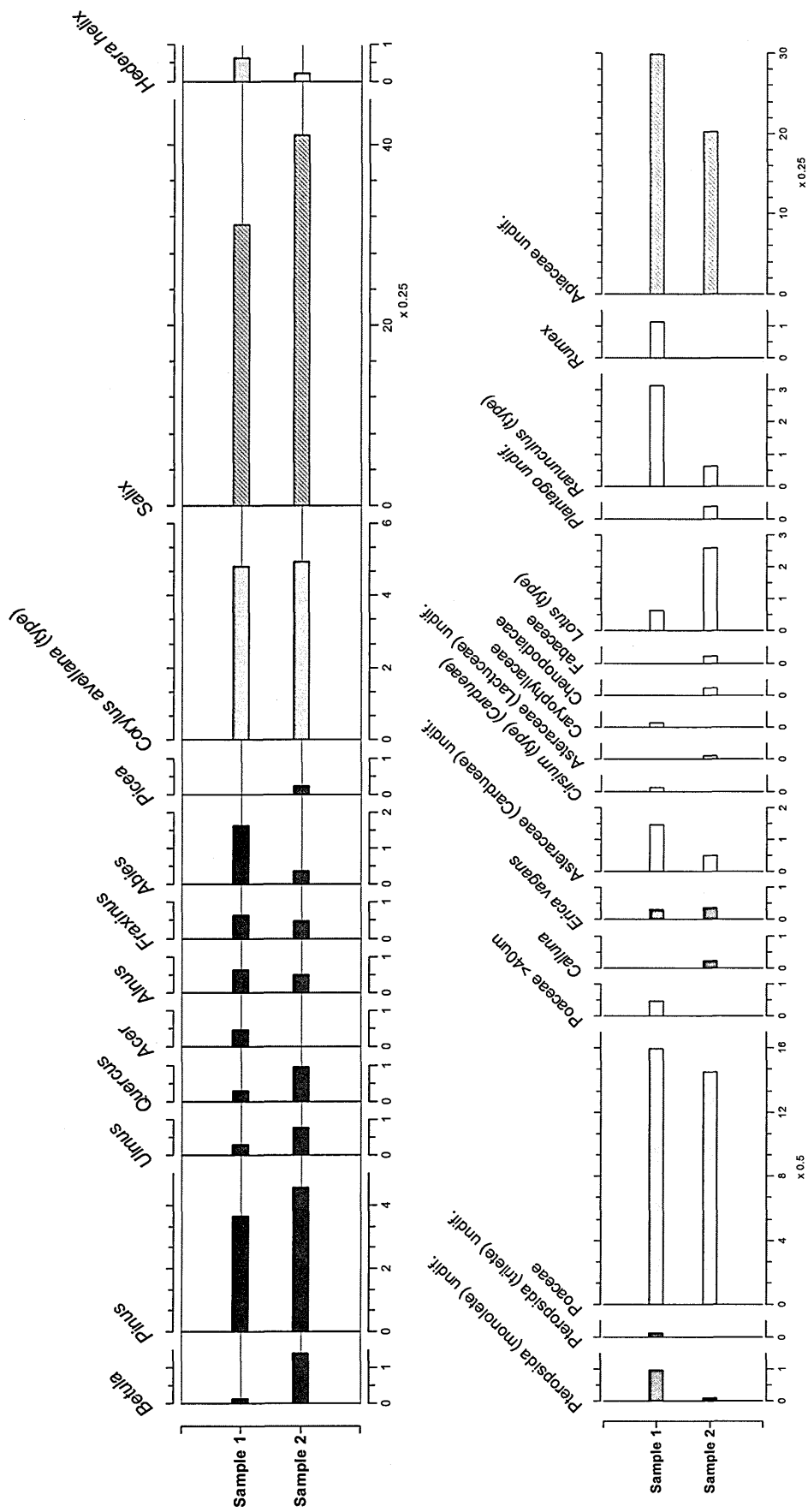


Figure 4.10 Hendra surface samples

Local pollen assemblage zone H1 (120 cm – 100 cm):

The ^{14}C calibrated dates for this zone are 7489 ± 64 to 5175 ± 125 years BP, a period of approximately 2,300 years represented by 20 cm of sediment, a result of very slow sedimentation or a possible break in the sedimentary record. At the bottom of the zone the pollen assemblage is dominated by *Pinus* with some *Betula* (ca. 60% of TLP) with the other significant contributions coming from *Corylus* (ca. 20%) and Caryophyllaceae (ca. 15%). The representation of *Pinus* pollen drops rapidly with the difference being made up principally by a large increase in the *Corylus* (type) pollen. *Ulmus*, *Quercus* and *Tilia* pollen appear during this lower part of the zone. During the top half of the zone the representation of *Betula* pollen doubles and *Alnus* pollen appears. Throughout the zone there is a significant representation of Fabaceae pollen with most of this being *Lotus* (type) pollen. The spore counts of *Polypodium* and Pteropsida (monolete) undiff. also remain very high throughout this zone at about 100% of the TLP. This zone is analysed in more detail in the pollen diagram from the HEN2 core (Figs. 4.11 to 4.14).

The depositional environment consists of a fine sand and clay mix over the basal ca. 8 cm changing to a fine sandy clay over the top 12 cm. Rootlets and leaf and stem detritus occur throughout.

Local pollen assemblage zone H2 (100 cm – 85 cm):

The ^{14}C calibrated dates for this zone are 5175 ± 125 years BP at 100 cm to 2230 ± 82 years BP at 85 cm. This is a period of about 3,000 years represented by 15 cm of sediment, an even slower sedimentation rate than through zone H1 increasing the possibility of there being a break in the sedimentary record at this horizon. This is supported by a ^{14}C calibrated date at 92 cm of 4383 ± 137 years BP, possibly indicating a loss of sediment between 92 cm and 85 cm. By far the most significant feature of this zone is the rapid rise in *Alnus* pollen at the expense of *Betula*, *Pinus* and *Corylus* (type) pollen. The *Alnus* count remains high at between 40% and 60% of the TLP until the top of the zone. At the bottom of the zone at 95 cm there is a significant increase in the pollen concentration suggesting that the *Alnus* pollen may be, at least in part, adding to the pollen representation rather than replacing it. For the remainder of the zone, however, the pollen concentration drops,

possibly indicating the replacement of the *Betula* and *Pinus*, whose pollen almost disappears, by *Alnus* and *Quercus*.

The *Quercus* pollen also increases from the base to the top of the zone and the *Corylus* (type) pollen although reduced remains high at about 30% of TLP. *Salix* pollen disappears towards the top of this zone and the only significant changes in the herbaceous pollen are a rise in the Asteraceae (Cardueae) and, towards the top of the zone, a rise in Cyperaceae and Apiaceae pollen. An unidentified Ericaceae grain appears at the bottom of the zone (neither *Calluna* or *Erica vagans*) and *Calluna* appears at the top of the zone. There were no *E. vagans* grains identified. Finally, the spore count increases dramatically in the top half of the zone to almost 200% of the TLP.

The depositional environment changes just above the top of the zone from a fine sandy clay mixture to a highly humified organic clay. Both sediment types are penetrated by roots and contain leaf and stem detritus.

Local pollen assemblage zone H3 (85 cm – 70 cm):

The ¹⁴C calibrated dates for zone H3 are 2230 years BP at 85 cm and 1237 years BP at 71 cm, a period of approximately 1,000 years represented in 14 cm of sediment. The changes in the pollen assemblage associated with this zone boundary are many and profound. The most distinctive is the drop in *Alnus* pollen from about 40% to about 5% of TLP. There is no recovery from this low pollen count. *Corylus* also decreases at this boundary, *Quercus* remains constant and *Betula* increases slightly.

The drop in the tree and shrub pollen count is largely absorbed by significant increases in the Poaceae pollen from about 5% to 35% with a similar but not quite so large increase in the Cyperaceae pollen. The increase in both these pollen curves is maintained to the top of the zone at 70 cm. Of possibly greater significance, however, is the first appearance of cereal type (Poaceae >40 µm) grains at this boundary and the maintenance of this curve also to the top of the diagram. The Ericaceae pollen, particularly *Calluna*, increase from almost non representation to up to 10% at this boundary. Interestingly, though, the *E. vagans* pollen is the least represented, quite the opposite to its representation in the higher regions of the

EBA2 and CPAI diagrams. Asteraceae (Lactuceae), Brassicaceae, *Plantago*, *Rumex*, Rosaceae and *Polygala* appear for the first time and all but Rosaceae and *Polygala* show sustained high levels of pollen throughout this zone. Apiaceae pollen appears and increases during the second half of zone H2 and this is maintained throughout zone H3. The spore frequencies of *Polypodium* and Pteropsida (Monolete) undiff. drop very rapidly at this horizon and do not recover, whilst *Pteridium* spores form a continuous curve for the first time from the first part of this zone.

The depositional environment through zone H3 is a highly humified organic silt with rootlets and leaf and stem debris occurring throughout. The bottom 5 cm contain less humified material, this being replaced by a fine sand.

Local pollen assemblage zone H4 (70 cm – 32 cm):

The boundary of zone H4 with zone H3 is marked by a significant drop in the *Quercus* pollen and in the Ericaceae pollen. This is absorbed largely by increases in the Asteraceae and Cyperaceae pollen. *Pteridium* spores disappear at this zone boundary as do some of the herbaceous pollen taxa. There is also a sharp but temporary decrease in grass, cereal type (Poaceae >40 µm) and sedge pollen and a corresponding temporary increase in Asteraceae pollen at 70 cm.

The depositional environment in zone H4 is principally an highly humified clay with rootlets and leaf and stem detritus. The minerogenic particles disappear towards the top of the zone.

Local pollen assemblage zone H5 (32 cm – 0 cm):

Zone H5 is characterised by falls in Asteraceae (Lactuceae), *Plantago*, cereal type and Cyperaceae pollen and rises in Poaceae, Apiaceae and *Salix* pollen and a small rise in *Pinus* pollen. The pollen assemblage from 10 cm, the final sample, corresponds closely to the surface sample assemblage (Fig. 4.10).

The depositional environment of zone H5 consists of highly humified material penetrated by rootlets and with much leaf and stem detritus. Over the top 20 cm the plant detritus consists of herbaceous plant fragments in excess of 2 mm in length.

iv) Surface sample pollen diagrams

Surface sample diagrams from the HENI core site were constructed in order to inform the interpretation of the main pollen diagram. Moss polsters from the branches of *Salix* trees growing on the surface of the mire were analysed for their pollen content. The diagrams for two moss polster samples are shown in Figure 4.10. They show a total tree pollen representation of between 15% and 26% of the TLP dominated by *Pinus* with some *Betula*, *Quercus*, *Ulmus* and *Abies* pollen, and a low representation of *Alnus*, *Fraxinus*, *Picea* and *Acer* pollen. *Corylus* (type) pollen is at a steady 5% and *Salix* between 30% and 40% of the TLP. The herbaceous pollen is dominated by Poaceae and Apiaceae and there is a very weak *Erica vagans* pollen representation of 0.8% of TLP. There is no Cyperaceae pollen and a very low representation of fern spores.

The surface sample pollen assemblage conforms closely to that of zone H5 of the HENI pollen diagram. Only the surface sample tree and shrub pollen representations differ significantly from zone H5. The *Pinus* pollen percentage of TLP increases slightly from 3% at 10 cm on the HENI diagram to 4% in the surface sample, *Ulmus* pollen is absent in zone H5 but constitutes 0.6% of the surface sample pollen, *Acer* and *Picea* pollen is present in the surface samples but not in zone H5. Of the shrubs, *Corylus* (type) pollen is almost absent in zone H5 but at 5% in the surface sample and *Salix* pollen increases from about 8% in zone H5 to 37% of TLP in the surface sample. The very low representation of the heathland pollen in zones H4 and H5 of the HENI diagram is corroborated in the surface samples.

4.4.4 HEN2 pollen analysis

The basal 25 cm of the HEN2 core was prepared and counted at 1 cm to 3 cm intervals, a total of 12 levels. The TLP count ranged from 125 from a very small amount of material to 626, giving an average of 430 grains per level (see Appendix VI). The total arboreal pollen

count (TAP) ranged from 62 from the small amount of material to 195, with an average of 118. The pollen taphonomy would be as for the HEN1 core. Pollen diagrams were produced from the base of this core because, although it duplicated much of the HEN1 core, it appeared to be slightly older at the base and pollen preservation was better. Initially samples were counted at 5 cm intervals, then intermediate samples were counted where pollen preservation made this possible and there was evidence of change in the pollen representation. Samples were counted every 1 cm between 113 cm and 117 cm in order to investigate further the occurrence of *Erica vagans* pollen at this depth.

i) The pollen diagram

The percentage pollen diagram was constructed using the total arboreal pollen (TAP) as 100%. The pollen diagram is shown in Figure 4.11 (trees, shrubs & charcoal), Figure 4.12 (herbs & aquatics) and Figure 4.13 (spores and indeterminate and pollen concentration). Figure 4.14 is a concentration diagram of the principal taxa. The sediment description column uses a modified Troels-Smith (1955) convention with a full key set out in Appendix V. The pollen diagram colour coding is also set out in Appendix V.

ii) Description of HEN2 pollen diagram

The period covered by the HEN2 pollen diagram corresponds to the basal local pollen assemblage zone H1 in the HEN1 pollen diagram and no further zonation has been identified. Of significance, however, is the high *Betula* count of 54% of TAP at the base of the diagram, slightly higher than the *Pinus* pollen count of 47% of TAP. This suggests that the basal sediment of the HEN2 core is slightly older than the HEN1 core where the much lower basal *Betula* count corresponds to the 117 cm *Betula* count of the HEN2 core. There

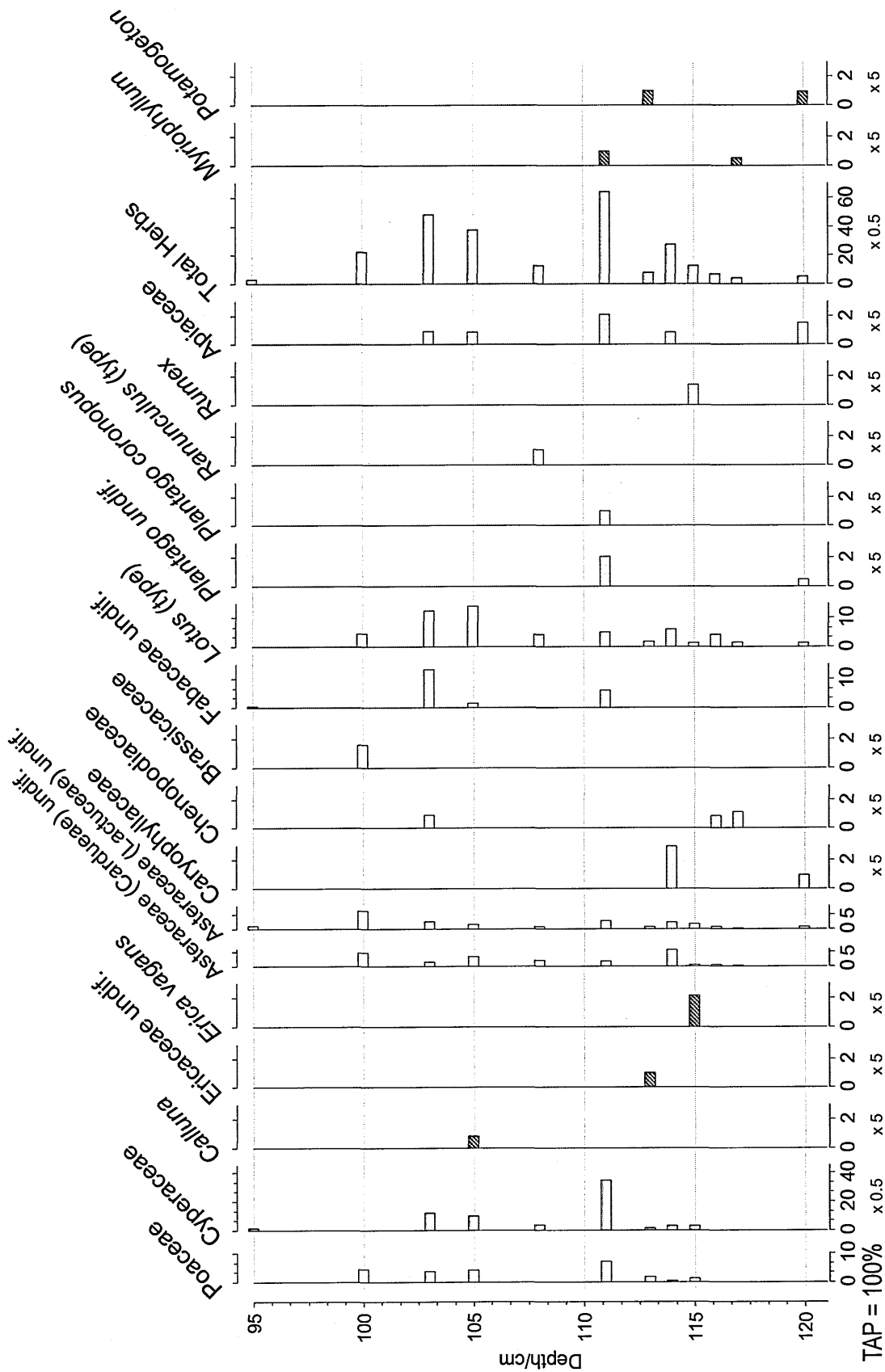


Figure 4.12 HEN2 Herbs and aquatics

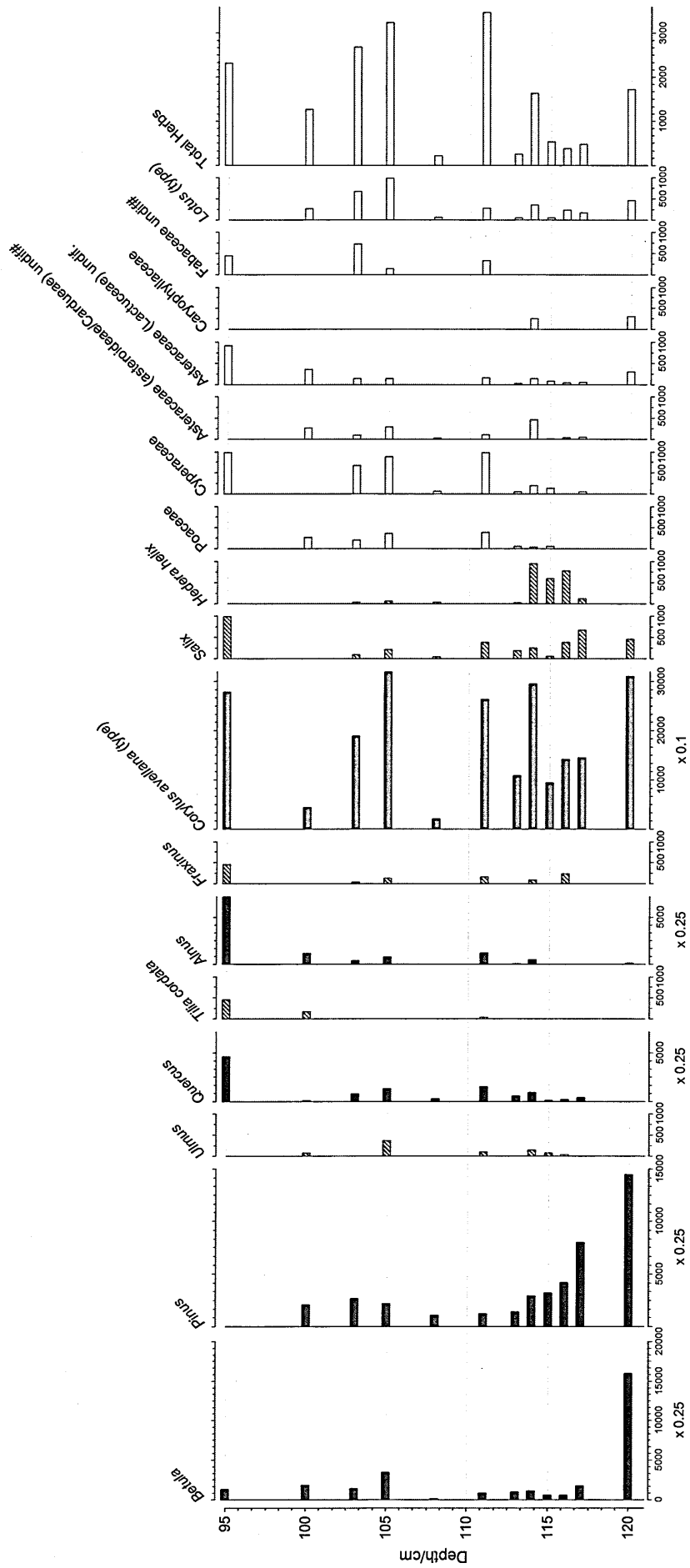


Figure 4.14 HEN2 Concentration diagram – selected taxa .
 Alnus bar truncated, max. value 60070 g⁻¹

All figures pollen g⁻¹
 dry weight

is no distinct Caryophyllaceae pollen peak at the base the HEN2 diagram as was found at the base of the HEN1 diagram.

The fall in tree pollen at 111 cm on the HEN2 core is indicated in both the percentage diagram (Fig. 4.11) and the concentration diagram (Fig. 4.14). In the concentration diagram, however, a much steeper fall in the tree pollen is evident at 108 cm, a steep drop in pollen concentration also being evident for shrub and herb pollen. Figure 4.14 also shows a steady fall in *Pinus* pollen concentration from the base of the core to 105 cm. The *Corylus* (type) pollen concentrations remain high throughout falling significantly only at 108 cm and 100 cm.

Chapter 5 DISCUSSION

In this chapter the data presented in Chapter 4 is further analysed and discussed. An interpretation is offered based on ecological, climatic and archaeological information, and palaeoecological evidence from previous studies. Data from the site with the longest archive, Hendra mire, is considered first and the Croft Pascoe and Erisey Barton data is considered within the context of the Hendra record. A chronology diagram linking the five cores discussed in this chapter by ^{14}C dates and synchronous pollen events is shown in Figure 5.1. Suspected unconformities in the depositional record are indicated.

5.1 Interpretation of Hendra sediment and macrofossil evidence

The following interpretation refers to the tabulated macrofossil data in Table 4.1 and Table 4.2. Zone A with its high wood and gravel content and frequent moss fragments appears to represent a forest catchment area with intermittent high energy inputs into the basin. There is no evidence of standing water and the frequent and common appearance of charcoal fragments, matched only by the charcoal in much younger sediments in zones C and D, suggests fire caused either by lightening or by anthropogenic forest disturbance. The GIS elevation map evidence (Fig. 2.10) indicates that this feature was part of the original drainage channel but became isolated, probably as the volume of water in the channel reduced. So the sedimentary context is of alluvial overbank or channel infill with an abandoned terrace. The sediments within the feature could represent deposition into the active channel but this would have been unlikely as the current would have scoured the stream bed. A more probable explanation is that the sedimentation commenced after the volume of drainage water reduced and that the banks of the drainage channel were only periodically overtopped bringing in sediment to the abandoned terrace. The water slowed sufficiently to deposit sediment but drained back into the active channel so no standing water developed.

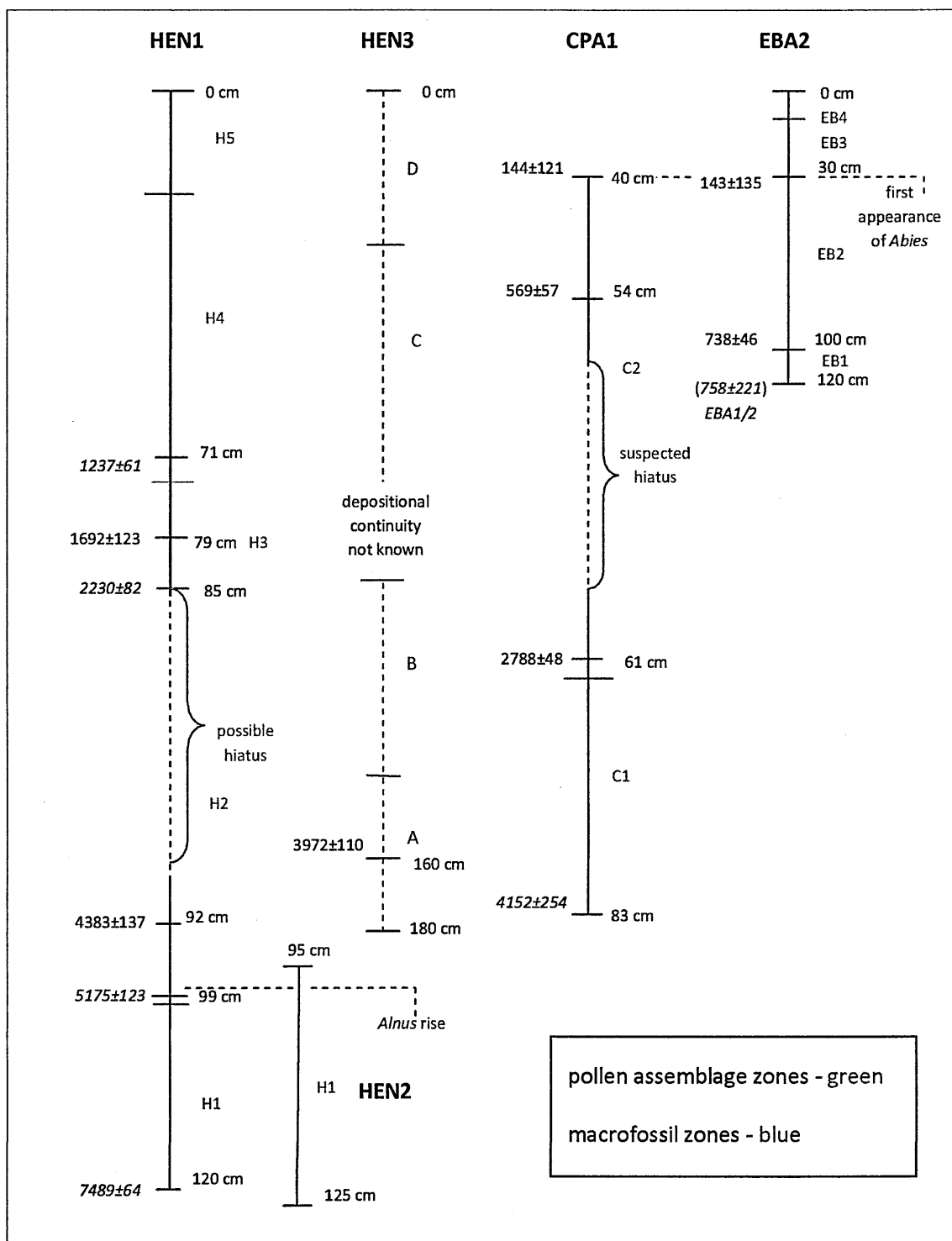


Figure 5.1 Chronological diagram of the five core sections used in this investigation. All ¹⁴C dates are in cal. yrs. BP, dates from bulk samples (minimum dates) in italics. Synchronisation is based on ¹⁴C dates and pollen evidence. Outliers have been excluded and the scale used is nominal.

The appearance of *Zannichellia palustris* seeds towards the end of this zone suggests that the build up of sediment slowed the stream down sufficiently for there to be intermittent standing water. *Z. palustris* is characteristic of very shallow stagnant or running water. Its short growing season enables it to colonise ephemeral freshwater habitats and its seeds are drought resistant (Van Vierssen, 1982). This ecology is therefore consistent with the scenario described above of intermittent flooding of an abandoned terrace. *Z. palustris* also provides some useful climatic information as its seeds require a stratification period of about two months at a maximum of 4° C and the optimum germination temperature is 24° C.

The basal section of zone B with the appearance of *Potamogeton* seeds and the abundance of *Z. palustris* seeds points to a more permanent body of standing water. The scarcity of aquatic pollen in the pollen diagram from the HENI core 50 m away however would suggest that this may have been rather limited in extent. The presence of mite and insect fragments and the more regular presence of *Juncus* seeds in the sediment suggest an increased rate of sedimentation with a surface flora growing possibly around the periphery of the basin. The relatively rapid drop in the numbers of *Z. palustris* seeds towards the higher section of the core in zone B suggests the progressive loss of the open water as the sediment built up.

Zone C provides a scenario much closer to the current nature of the feature. *Juncus* seeds are common or frequent in almost all the samples and *Carex* spp. seeds appear regularly. The biconvex seeds, possibly *Carex nigra* (L.) Reichard, occur only in the older parts of the core and following the disappearance of *C. nigra* type seeds triagonal *Carex* seeds appear frequently in the younger sediments. These seeds are consistent with an identification as *C. acutiformis* Ehrh. and/or *C. riparia* Curtis. *C. nigra* is characteristic of mires in which there is some surface water movement while *C. acutiformis* and *C. riparia* are more frequently associated with wet meadows and stream edges (Jeremy & Tutin, 1968). The only evidence of standing water in this zone is the regular appearance of Charophyte oospheres. This group of usually freshwater algae can occur, often as pioneer species, in almost any body of clear, still or slow flowing water and are common in ditches and gravel pits as well as lakes (Peck, 1946). The interpretation which most closely fits this assemblage is therefore of a sediment filled depression initially with some surface, flowing water with shallow pools but

slowly drying out as the sediment builds through the period. Towards the youngest part of this zone charcoal fragments become frequent or common possibly related to an increase in anthropogenic activity in the vicinity.

The final zone D identified from the macrofossil assemblage is very similar to zone C but the *Carex* spp. have largely disappeared and the Charyophyte oospheres no longer occur. This points to further drying out with a lack of surface water for at least part of the year. *Juncus* seeds are frequent or common in all but the top 5 cm of the core. *Juncus subnodulosus* is currently a significant component of the mire surface flora as are *Oenanthe crocata* and *Eupatorium cannabinum* whose seeds were occasional to frequent in the top 10 cm of sediment. Two specimens of the bivalve *Pisidium* confirm the presence of water on or just below the surface of the mire throughout the year.

A ^{14}C calibrated date of 3637 ± 110 years BP from wood fragments collected from a 160 cm sediment sample suggests that most of the sediment in the HEN3 cores has been deposited over the past 4,000 years. This interpretation therefore appears to provide a chronology for the development of the Hendra mire feature since ca. 4000 years BP. However, the possibility that the wood fragments were of root rather than aerial parts cannot be excluded. The older sediments to the western side of the mire from which the HEN1 and HEN2 cores were extracted must have been unaffected by the events that may have scoured out the sediments closer to the drainage channel. The ^{14}C calibrated age of the wood fragments, if they are of anthropogenic origin, may provide a date for the clearance of the woodland in the vicinity of the mire as Early Bronze Age. This period corresponds to 'muted' evidence for a cooler, wetter period identified by Charman (2010) which could support the clearance hypothesis as farmers may have been driven down from the higher ground. An alternative and more plausible explanation is that the wood fragments have resulted from the presence on the mire of an Alder carr as indicated by the *Alnus* pollen spike (Fig. 4.7) that spans the wood fragments date.

5.2 Pollen diagram interpretation

To reconstruct the past environments represented by these pollen diagrams the 'indicator species' approach as described by Turner (1964) will predominate. The interpretation draws on the guidance in Behre (1986) and the overview of the vegetation of the British Isles in Tansley (1968). The ecological information in identification guides (e.g. Clapham *et al.*, 1968; Tutin, 1980) is also used. The interpretation of the charcoal fragment count is informed by Patterson *et al.* (1987) and Clark (1988b).

The cores from the Hendra mire site provide the longest palynomorph record of the current study so are interpreted first. Pollen diagrams from the Croft Pascoe and Erisey Barton sites can then be considered within the context of this interpretation.

5.2.1 Hendra Mire HEN1 - pollen diagram interpretation

The pollen assemblage in zone H1 (7489±64 to 5175±125 ¹⁴C cal. years BP) appears to represent an initially heavily forested area, firstly by birch and pine and later by oak, alder and hazel. The picture provided is of a somewhat open forest dominated by pine and birch but in which hazel is also well established. The Caryophyllaceae pollen probably represents a very local stream side community of stitchwort such as *Stellaria uliginosa* Murray or *S. nemorum* L. Of interest is the non-appearance of this Caryophyllaceae flush in the HEN2 core collected about 1 m away but its appearance in the pilot diagram from spot samples taken from a core collected in the vicinity of the later cores. This points to a very local appearance of the Caryophyllaceae flush in either time or space. The relatively high representation of *Lotus* (type) pollen, even at a time when the forest canopy would have been largely closed, is best explained as the local appearance near the mire of *Lotus pedunculatus*, extant on the mire and elsewhere in the vicinity. The very high spore count reinforces the interpretation of the environment as a forest, with fern spores contributing almost all the trunk space non tree palynomorphs. The H1 zone is duplicated in the higher resolution HEN2 diagram where it will be considered in more detail (section 5.2.2).

The most significant feature of the base of zone H2 (ca. 5175 ± 125 to 2230 ± 82 cal. years BP) is the fall in *Pinus* and *Betula* and the rise of *Alnus* pollen. It is significant that the demise of the early birch/pine forest at 5175 ± 125 cal. years BP appears to occur up to 3000 years later than elsewhere in the British Isles (e.g. Groves *et al.*, 2012), although this must be qualified by the fact that this is a minimum date (see section 3.7). Groves and his co-workers note a fall in pine at 6050 cal. years BP at Conford in Hampshire. They attribute the persistence of pine in this Hampshire site to be the result of the low soil fertility and frequent fires, both of which appear to be true for the Hendra site with increased levels of large charcoal fragments just before the *Alnus* rise. Frequent water-logging, still a current feature of the Lizard plateau (e.g. Hopkins, 1983), may also have been a contributory factor to the late establishment of broad leaf forest as described by McVean (1956), see below. Groves *et al.* (2012) list a number of southern England lowland heath sites where *Alnus* replaces *Pinus* when the latter falls below about 20% of the TLP which is the case at Hendra.

A useful insight into this alder rise is provided by Bennett and Birks (1990). They reviewed the alder pollen data from 92 ^{14}C dated sites throughout Britain and Ireland recording the time at which a continuous alder curve first appeared, and the age at which the curve reached its maximum. They noted that the appearance and rapid rise of alder pollen, as indicated by the HENI diagram, occurs at many of these sites and that the timing of the alder arrival during the Holocene is not simply time-transgressive but 'patchy' in both space and time. They suggest that this may be due in part to the very specific requirements for establishment and regeneration for alder described as 'wet lowland islands within a sea of better drained soils'. McVean (1956) described the establishment of alder sapling populations requiring abnormally high water tables following unusually high rainfall or snowmelt events. The other important factor considered by Bennett and Birks (1990) is the patchy manner in which suitable alder habitats appeared as a result of sea-level changes, isostatic uplift, hydroseral successions and floodplain developments. Increasing wetness on the Lizard peninsula at this time is hinted at by the synchronous rise of the Pteropsida spores, and by Charman (2010) who suggests 'muted' evidence for a wetter period at ca. 4200 years BP. It may well be, however, that the Hendra *Alnus* rise is a local event related to relatively localised water table changes in the shallow valley in which this site is situated

on the lower slopes of the plateau. Beckett (1981) shows how alder pollen curves can vary greatly even in neighbouring sites.

The ^{14}C dates at the base and top of zone H2 suggest a ca. 3,000 year period, from 5175 ± 123 to 2230 ± 82 cal. yrs BP, during which there was little change in the forest vegetation. It apparently spans a period in which there was considerable human disturbance of the environment elsewhere in the British Isles encompassing both the Neolithic and the Bronze Age. However, it appears that the broadleaf forest of elm, oak, lime and hazel that followed the birch and pine elsewhere in the British Isles (e.g. Godwin, 1975) never fully developed here. Rather there was a period when the extra-local forest in the vicinity of the Hendra site was dominated by alder with oak and hazel. The rise in *Alnus* pollen representation coincides with an increase in the *Quercus* pollen from 1% to 6% of the TLP and a fall in the *Corylus* (type) pollen from 70% to 20%. Both these pollen frequencies would have been suppressed by the very high *Alnus* pollen count so this suggests that, if the *Alnus* rise at Hendra is the result of a relatively local increase in alder, an oak/hazel forest may well have been present in the drier areas beyond the Hendra site.

The lack of wood in the HEN1 sediment at this horizon and the relatively low pollen concentrations initially suggested that the alder pollen was produced from the extra-local catchment rather than as the result of the development of alder carr on the surface of the Hendra mire. The dating of wood fragments from the HEN3b core at a ^{14}C date of 3972 ± 110 cal. years BP supports the view that the *Alnus* pollen spike that spans this wood fragment date is derived from a localised Alder carr. There is no sign of an alder dominated tree pollen assemblage on the CPA1 pollen diagram even though the base covers an only slightly later ^{14}C time period as zone H2. All this tends to point to the rapid rise of the alder curve at the start of zone H2 of the HEN1 diagram as being a local feature probably resulting from a rise in the water table. The possibility of a rapid rise in the alder pollen curve resulting from anthropogenic factors such as burning and clearance has been mentioned by a number of workers (e.g. Smith, 1984) and, although criticised by Birks (1989), cannot be discounted here. The very large increase in the fern spores towards the end of the H2 zone occurred at ca. 4383 ± 137 cal. years BP and so broadly coincides with

the ‘muted evidence’ for a cooler, wetter climate 4200 to 4000 years BP highlighted by Charman (2010) and the onset of the cooling period identified by Lamb (1977).

The apparently slow sediment accumulation rate along sections of the core may have resulted in a very low resolution of the pollen record. However, the abrupt change in the pollen and spore assemblage between zones H2 and H3, particularly that of the spores, is possibly the result of an unconformity in the sediment. The six ^{14}C dates currently available for the HEN1 core are shown in the age/depth plot below (Fig. 5.2). It shows a relatively constant accumulation rate over the earliest 6,000 years followed by a much more rapid accumulation rate over the latest 2,000 years. There are equivocal signs of a hiatus in Figure 5.2 and, based also on the accumulation rates (Table 5.1), the position of a possible loss of sediment is indicated on the graph.

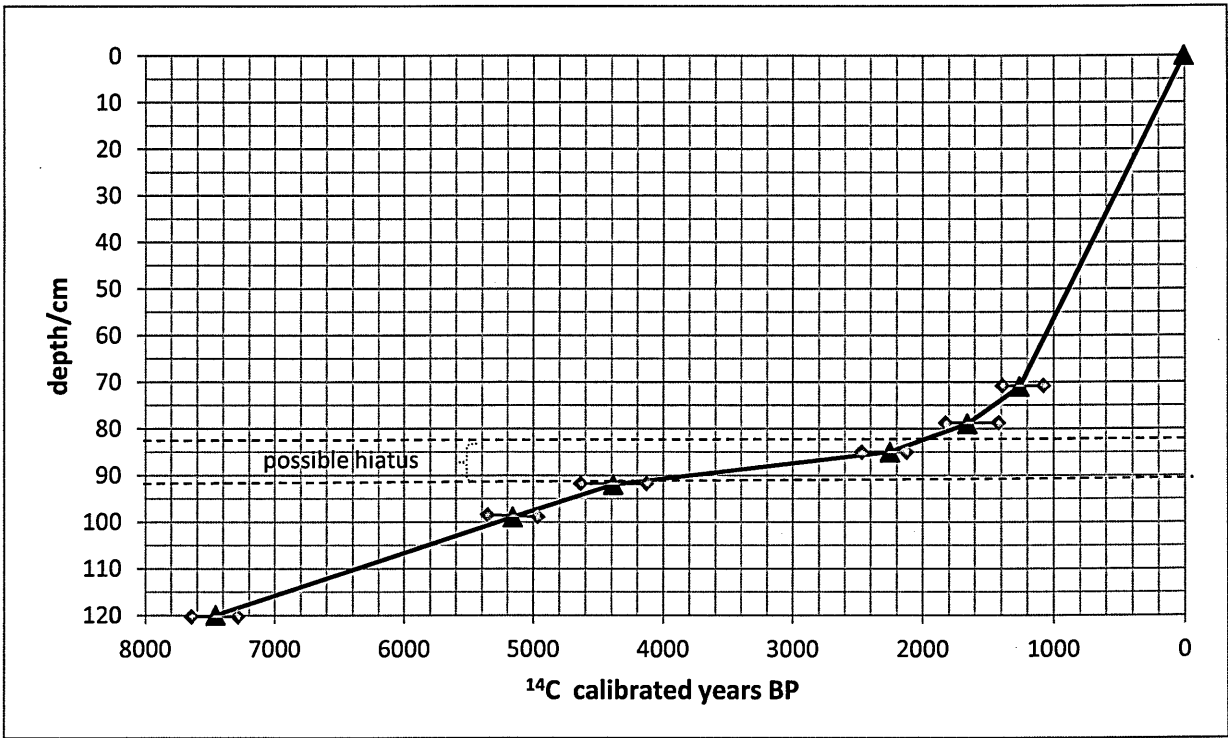


Figure 5.2 HEN1 age - depth graph

The accumulation rates between each ¹⁴C date are shown below in Table 5.1. The sediment within the putative hiatus depth range has an accumulation rate approximately three times that of the sections above and below suggesting that there may have been a loss of material representing approximately 2,000 years of deposition between 92 cm and 85 cm. Evidence from the sediment description indicates a change from a sandy clay below the putative hiatus to a highly humified clay above although this change occurs 5 cm above the assumed unconformity. The evidence for a hiatus is therefore incomplete and the possibility that this section of the pollen diagram represents a very low resolution of a temporarily contiguous pollen archive cannot be discounted.

Table 5.1 ¹⁴C calibrated dates for the HEN1 core and average sediment accumulation rates.

¹⁴ C sample depth/cm	¹⁴ C median cal. yrs BP	yrs diff.	accumulation rate yr/cm ⁻¹	accumulation rate cm/yr ⁻¹
[0]	[0]			
		1237	17.4	0.057
71	1237±61			
		455	56.9	0.018
79	1692±123			
		538	89.7	0.011
85	2230±82			
		2158	308.3	0.003
92	4388±137			
		787	112.4	0.009
99	5175±125			
		2314	110.2	0.009
120	7489±64			

The rapid accumulation rate over the most recent 1000 years is also evident at the Croft Pascoe site and may be related to the establishment of *Phragmites* on the mire surface adding considerable amounts of plant material to the surface of the mire annually.

Zone H3 appears to represent an environment dominated by anthropogenic activity. At some time before these sediments were laid down much of the oak/alder/hazel woodland has been cleared and replaced by grasses and sedges. The simultaneous appearance of *Plantago* spp., *Brassica* and cereal type pollen supports this interpretation. The Ericaceae pollen also increases abruptly at this horizon. The HEN1 pollen assemblage represents pollen transport from the higher ground to the west, and the opening up of the canopy would allow pollen transport from the top of the plateau to the north by rain transport. The rise in the representation of Ericaceae pollen in zone H3 may therefore result equally from an increase in heathland species in the extra-local landscape of the Hendra mire and heathland development on the higher regions of the plateau to the north and west. The possibility that the Ericaceae pollen has originated from the development of these species on the mire surface is not supported by the macrofossil evidence from the HEN3 cores that indicate the presence of surface pools for much of the period following 4,000 years BP (HEN3 Zones B and C). The Hendra surface samples and zones H4 and H5 show a much reduced representation of Ericaceae pollen despite the high Ericaceae representation in the upper regions of the other pollen diagrams in this study and the extant Ericaceae rich heathland on Goonhilly Downs. This suggests that the zone H3 Ericaceae is of largely local and extra-local origin and its subsequent disappearance at the start of zone H4 represents a change in the flora, probably resulting from a change in land use.

The herbaceous pollen in zones H3 and H4 suggests a range of habitat types. The zone H3 assemblage includes Rosaceae (identified as *Sanguisorba* sp.) and *Polygala* sp. alongside *Calluna* and other Ericaceous species. These suggest a grassy heathland habitat alongside the cultivated fields supporting cereals. The appearance of *Pteridium aquilinum* spores during this episode is significant and may indicate land management practices such as burning. Zone H4 shows a fall or disappearance of all the pollen and spores mentioned above and a rise in Asteraceae particularly Lactuceae, Brassicaceae and *Plantago* pollen. These taxa all tend to be associated with a much more disturbed habitat possibly indicating an increase in the human

population and consequent increasing agricultural activity. Further data from this section of the core may be required to inform an interpretation of this pollen assemblage event.

Zone H5 appears to represent a further change in land use with a reduction in agricultural activity, particularly arable, indicated by the decrease of cereal type large Poaceae pollen, the weed species Asteraceae (Lactuceae) and *Plantago*, and an increase in (small) Poaceae. Increases in Apiaceae and *Salix* pollen linked with a decrease in Cyperaceae pollen suggest changes in the vegetation on and around the mire possibly linked with increased wetness. A similar taxa representation is evident in the HEN3 macrofossil analysis in Zone D, the top 40 cm. The frequency of *Carex* fruits is much reduced and *Oenanthë crocata* seeds appear. These changes are also mirrored in the surface samples with their very high representation of *Salix* and Apicaceae pollen, the latter almost certainly deriving from *O. crocata*, currently abundant on the mire surface. The possible synchronicity of the fall in Cyperaceae pollen at the base of Zone H5 in the HEN1 diagram and the fall in frequency of *Carex* fruits in Zone D of the HEN3 macrofossil table is a strong indication that the Cyperaceae pollen is derived largely from the mire surface rather than from the extra local pollen catchment.

The representation of the *Corylus* type pollen at 5% of the TLP in the surface sample is not reflected in the final 10 cm and 20 cm samples on the HEN1 diagram but the 4% representation of *Pinus* in the surface sample is evident on the diagram by a significant rise of up to 4% of the TLP in *Pinus* pollen in the final two samples. This rise in *Pinus*, also present at the top of the Erisey Barton and the Croft Pascoe diagrams, is probably the result of the establishment of forest plantations on the Lizard Peninsula during the 19th and 20th centuries. Similar 19th century *Pinus* pollen increases are found in the two southern lowland heathland sites investigated by Groves *et al.* (2012) and are thought to be the result of local pine forest expansion at this time. The contribution of long distance transport of the saccate *Pinus* pollen will also be significant throughout the region at this horizon.

5.2.2 Hendra Mire HEN2 - pollen diagram interpretation

The HEN2 percentage pollen diagram is based upon total arboreal pollen (TAP) representing 100%. This should provide a clearer representation of the relationships between the trees

in this apparently forested pollen catchment. The smaller sampling intervals of the basal 25 cm of this core with total arboreal pollen (TAP) counts of 90 or more (with one exception) provide a much higher resolution of the pollen assemblage and a fuller representation of the tree pollen in this zone than the HEN1 diagram. The AMS ^{14}C dates from 120 cm on the HEN1 core provide an age of 7489 ± 64 cal. years BP while the mixture from the base of HEN1 and HEN2 cores (113 – 123 cm) gives a standard radiometric ^{14}C date of 7580 ± 160 cal. years BP. Possible root contamination means that these dates must be considered a minimum age. The AMS ^{14}C date for the start of the rapid rise of *Alnus* at 99 cm on the HEN1 core is 5175 ± 125 cal. years BP and this event is matched by the 100 cm sample on the HEN2 core. This therefore infers that the deepest 20 cm of the HEN2 core represents a period of ca. 2,400 years.

The pollen assemblage from this deepest 20 cm appears to represent a closed *Betula-Pinus* forest. The *Betula* proportion of the TAP ranges from 13% to 52%, and the *Pinus* pollen from 22% to 78%. The consistently high spore count, predominately *Polypodium* and *Pteropsida* (monoletes), and the very low herb pollen count throughout this period tend to support this interpretation. The remaining tree pollen sum comes from a smooth *Quercus* curve and an intermittent *Alnus* curve. *Ulmus* and *Tilia* pollen are present. Single *Alnus* pollen grains appear at 120 cm, 117 cm and 115 cm before appearing more regularly from 116 cm. The Hawkes Tor diagram from Bodmin Moor in Brown (1977) has the first appearance of *Alnus* and *Quercus* pollen ^{14}C dated at 9061 ± 160 uncalibrated (10172 ± 478 cal.) years BP while at Dozmary Pool the *Alnus* rise postdates the *Quercus* rise with an uncalibrated ^{14}C date of 6451 ± 65 (7368 ± 110 cal.) years BP. Even this second date is earlier on Bodmin Moor than the first regular appearance of *Alnus* pollen at Hendra at 116 cm on the HEN2 core as is the first appearance of *Quercus* at 117 cm. The *Alnus* and *Quercus* at the Hendra site appear to have arrived between ca. 7489 and 5175 cal. years BP. The *Quercus* arrival at Hendra appears to be considerably later than at Bodmin Moor but the *Alnus* arrival only a little later. This discrepancy may be exaggerated by root contamination of the bulk samples from which the Hendra ^{14}C dates were taken.

The *Corylus* type pollen increases throughout this episode up to 500% of the TAP at 111 cm. This peak coincides with a temporary drop in *Pinus* and *Betula* and a rise in *Poaceae*,

Cyperaceae, Asteraceae, Fabaceae, Apiaceae and *Plantago* pollen. This hints of forest disturbance and a temporary opening of the canopy in the vicinity of the Hendra site although the low charcoal count of both large and small fragments during this period could infer a large but more distant clearing. The concentration diagram (Fig. 4.14) has been constructed in order to analyse this possible disturbance further. It shows a very large concentration drop in all the pollen taxa at 108 cm (tree, shrub and herb) to almost zero. At this same horizon the spore count reaches its highest at almost 300% of the TLP (700% of the TAP). This infers that the forest in the vicinity of Hendra mire has been severely disturbed reducing tree, *Corylus* and herb coverage with the opportunistic ferns, Pteropsida (monolete) undif. and *Polypodium*, proliferating in the cleared areas. The ^{14}C dates from the HEN1 core point to the possibility of this being a Mesolithic clearance. Mellars (1975) and others have described evidence for the production of woodland clearances by Mesolithic people to manage the ungulate population and to encourage hazel (see section 1.5.1) and the HEN2 diagram supports this with a rise in the *Corylus* type pollen following the pine/birch fall. The concentration diagram shows that only the *Corylus* type pollen returns to its previous higher concentrations, the *Betula* and *Pinus* curves only partially recover before almost disappearing at 95 cm with the rise of *Alnus*. The fluctuating but predominantly decreasing tree pollen concentrations from 120 cm to 100 cm, however, suggest that the forest may have been in decline throughout this period.

At 95 cm the *Alnus* pollen increases considerably, from 21% of TAP at 100 cm to 80%, with a corresponding drop not only in the tree pollen but also in the pollen of shrubs and herbs. This *Alnus* peak enables the HEN2 diagram to be synchronised with the HEN1 diagram where the *Alnus* peak also occurs at 95 cm. The nature of this *Alnus* spike has been discussed in section 5.2.1. Both HEN1 and HEN2 diagrams show a peak in both large and small charcoal fragments immediately before the spike but a detailed analysis in the changes in the pollen rain during the period of rising *Alnus* has not been possible due to very poor pollen preservation over this 5 cm of sediment.

The HEN2 diagram may throw some very tentative light on the origins of the endemic *Erica vagans* in the Lizard Peninsula. Three grains of *E. vagans* were identified in the 115 cm

sample (<1% of TLP) but as yet no further grains have been found until the 85 cm HEN1 sample dated at 2230 ± 82 cal. years BP when ten *E. vagans* grains were found (4.2% of TLP). The few *E. vagans* grains at 115 cm, although a very tentative indicator of the presence of *E. vagans* in the post glacial forest, support the recent finding of an *E. vagans* (*E. ciliaris* type) dominated heathland flora in the late Devensian just north of the Lizard Peninsula at Carnmenellis (Forster et al., 2011). Both these findings would weaken the case for an anthropogenic explanation of their introduction at this very early time. They lend support to the explanations involving the spread of the species from local glacial refugia, or more probably the rapid post glacial migration from the south of Europe along its now drowned western seaboard. Further *E. vagans* grains need to be found at Hendra before this finding can form a significant part of the debate but examination of the 114 cm and 116 cm samples from the HEN2 core, on either side of the 115 cm core, have not duplicated the finding.

5.2.3 Croft Pascoe - pollen diagram interpretation

The pollen assemblage of zone C1 suggests a relatively open landscape with the tree and shrub pollen contributing between 19% and 27% of the TLP. This tree and shrub pollen may represent a pollen signal from forest cover down slope from the plateau or from copses and boundary features closer to the sample site. Much of the Poaceae and Cyperaceae pollen might be accounted for by the flora on the surface of the linear feature in which the sediment is dominated by monocotyledonous leaf and stem fragments through most of its depth. However, with a Poaceae pollen percentage of up to 45% of the TLP it is likely that there was a significant contribution from the surrounding plateau.

This herbaceous pollen assemblage persists for ca. 1400 years between 4152 ± 254 and 2788 ± 48 cal. yrs BP. The compelling interpretation is of an open, anthropogenic landscape in which both arable and pastoral agriculture are taking place in the vicinity of the sample site. With the low but steady Ericaceae pollen representation it may be described as an embryonic 'tall heath' community as described by Coombe and Frost (1956). The large Poaceae grains are discussed in Section 3.3.2 with a strong suggestion that they belong to

the *Hordeum* group of cereals. In addition, the relatively high contribution of *Plantago* pollen, up to 7% of the TLP, and the near permanent presence of Asteraceae, *Ranunculus*, *Rumex* and Caryophyllaceae pollen support an anthropogenic interpretation of the landscape type (e.g. Behre, 1981; Turner 1964). The coarse sand and gravel depositional environment support the view of this being a disturbed environment with grazing and ploughing resulting in a minerogenic run off into the feature.

In his analysis of Bronze Age soil from the Croft Pascoe area Smith (1984b) describes a similar pollen assemblage to that of zone C1 but he speculates that the cereal type and *E. vagans* pollen may have been washed down from the modern soil. However, the continuous *E. vagans* curve within the Croft Pascoe core, rising rapidly from 61 cm with minimal evidence of downwards pollen transport, and the disappearance of the large Poaceae pollen grains just before this point, support the interpretation of these two taxa being representative of the flora of the catchment area at the time of the sediment deposition.

The increase in Pteropsida (monolete) spores towards the top of Zone C1 could be linked to a change to cooler and wetter conditions and the consequent abandonment of arable agriculture on this area of Lizard peninsula. Charman (2010) notes strong evidence for just such a change in the climate between 2800 and 2700 years BP. Evidence from testate amoeba and peat humification on Dartmoor (Amesbury et al., 2008) identifies a cooler and/or wetter climatic period between ca. 3345 and 3105 years BP. These dates are at or older than the CPA1 ^{14}C date at 61 cm of 2759 cal. years BP. The palynomorph evidence for the possible abandonment of arable farming occurs at 65 cm so lending support to the hypothesis that climate deterioration was a significant factor in forcing this change.

The final significant features from this zone are continuous curves of *Plantago coronopus* and *Lotus* type pollen that extend into Zone C2. These may be interpreted as specifically associated with an abundant but distant cliff top flora. Such a suggestion for a more diverse cliff top flora was made by Tinsley (in Lawson-Jones, 1999) in her analysis of the pollen diagram from the peat samples obtained during the Porthleven flood alleviation scheme. Neither *Lotus coronopus* nor *L. pedunculatus* are significant members of the present day cliff

top flora however (Mallock, 1971; Hopkins, 1983). The presence of the *Lotus* type pollen in almost every sample counted during the course of this study is therefore most likely explained by the ubiquitous nature of *L. pedunculatus* in the flora surrounding wet features.

The C1/C2 zonal boundary is marked by significant falls in the tree and shrub pollen and a rapid rise in the Ericaceae pollen, particularly *Erica vagans*. The four taxa that appear to become more scarce following the increase in the Ericaceae; Asteraceae (carduae), Caryophyllaceae, Chenopodiaceae and Ranunculaceae, are all associated with anthropogenic habitats, particularly footpaths and ruderal communities (Behre, 1981). Large Poaceae cereal type grains still occur but a total of only 5 in the ten levels analysed in zone C2 compared to 41 grains in the nine levels of zone C1. The *Plantago* and Asteraceae (Lactuceae) pollen representations are slightly higher than their previous levels, however, and Poaceae only slightly reduced, probably an artefact of the steep rise in Ericaceae species curves.

The most likely environment that produced this assemblage is a largely open heathland with some pastoral agriculture occurring but with little arable farming. The dominance of *E. vagans* in the heathland flora is consistent with the heathland assemblage of the medieval to modern period recorded in the Erisey Barton pollen diagram, Figure 4.1, on the southern edge of the Downs. The apparent hiatus indicated by the ^{14}C dates shown in the age depth graph (Fig. 5.3), the rapid rise in the *E. vagans* pollen and the fall in the *Corylus* type pollen suggest that sediment representing about 2,000 year of deposition has been lost and the zone C2 assemblage has been produced by an anthropogenic medieval to 19th century landscape. It is significant that there is a distinct change in the sediment at this horizon, from a gravelly minerogenic one below the putative hiatus to a more organic, humified one above. The missing 2,000 years of the pollen archive may well have been the result of the 'Turbaries', peat and turf digging activities reported by Halliday (1953) and Hopkins (1983) as common on Goonhilly Downs from medieval times until the 17th century. Most of the evidence for this activity arises from contemporary accounts rather than physical evidence, however.

The final sample at 39 cm shows a slight increase in *Pinus* pollen, but more significantly the appearance for the first time of pollen of the exotic conifer *Abies*. This, along with the ^{14}C

cal. date of 144 ± 121 years BP (1806 AD) is very convincing evidence that the top 40 cm of the Croft Pascoe sediment was deposited within the last 200 years. The slight fall in the Ericaceae and Poaceae pollen in the 39 cm sample is almost certainly an artefact of the rapid rise in Cyperaceae pollen at this horizon, from 22% of the TLP at 45 cm to 49%. This final

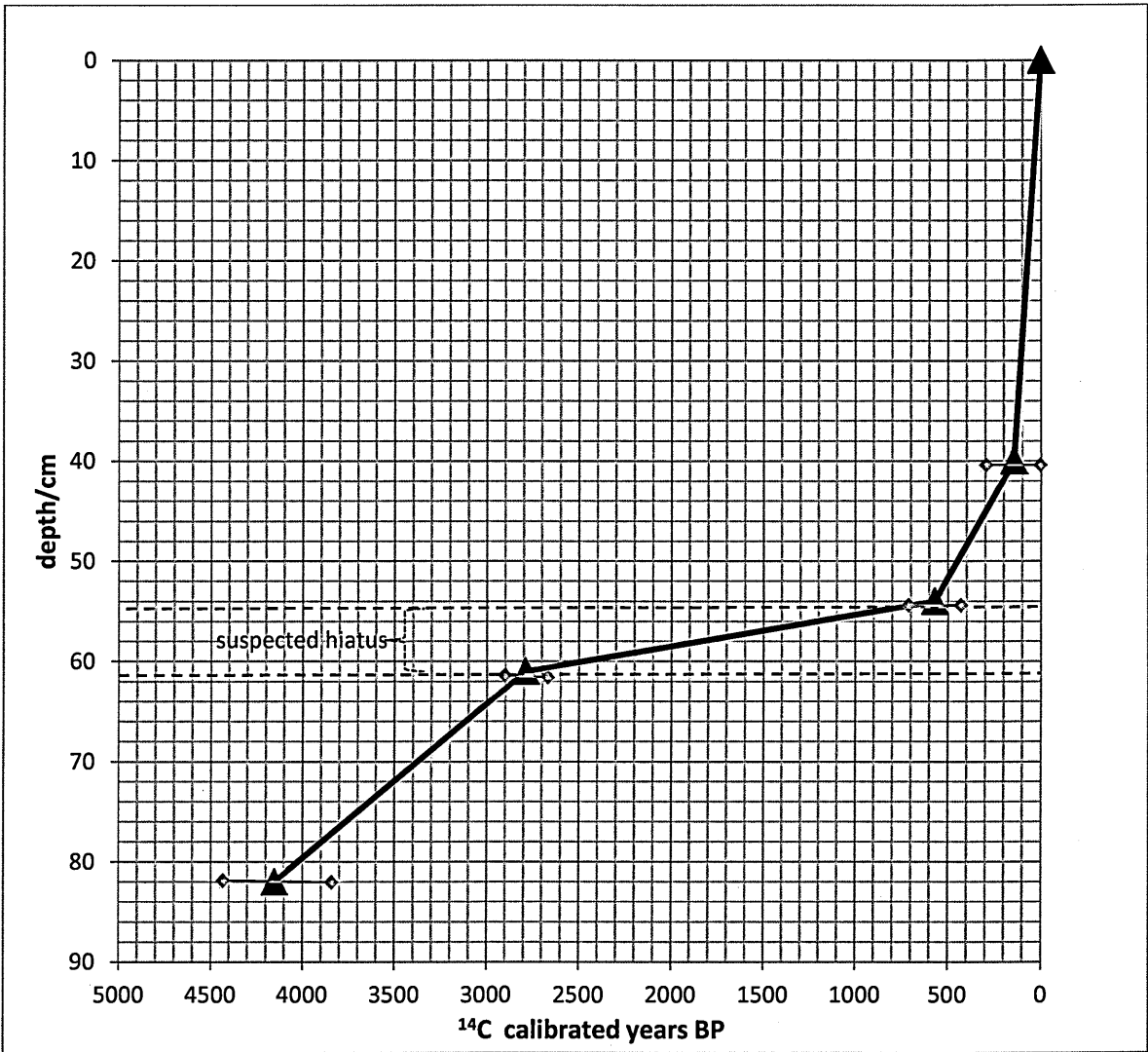


Figure 5.3 CPA1 median ^{14}C cal. years – sediment depth graph

pollen assemblage can therefore be seen as a precursor to the extant flora of the area consisting as it does of heathland, rank grasses, *Phragmites* and conifer plantations. The surface sample pollen assemblage, Figure 4.6, shows a similar pattern but with a significantly

higher *Pinus* pollen count. The very high Pteropsida spore count in this surface sample at 220% of the TLP appears to be the result of the presence of *Athyrium filix-femina* alongside the *Phragmites* within the main channel of the feature.

The rapid sediment accumulation rate over the most recent 500 to 1000 years compared to that of the Bronze Age period may indicate a very different depositional environment over this most recent period. The growth of *Phragmites* along the feature, for example, would result in a rapid annual accumulation of plant material if it were not cut and removed. The sediment description identifies *Phragmites* peat from the surface of the sediment down to about 40 cm, the period of most rapid sedimentation.

5.2.4 Erisey Barton - pollen diagram interpretation

The ^{14}C calibrated dates for the first of the four Erisey Barton zones, EB1, indicate a date of 758 ± 221 years BP at the base (ca. 1192 AD) and 738 ± 46 years BP at 100 cm (ca. 1212 AD). However, the basal date was produced by standard radiometric dating using 45 g of material from the base of two cores, EBA1 and EBA2, so is an average age of this large portion of sediment from the base of the feature. As such it can be considered as a significantly more recent date than the true date of the base of the cores and that the zone probably spans more than the 20 years that these ^{14}C dates suggest. The pollen assemblage is indicative of an open, lightly grazed landscape in an open valley in which the millpond had not yet fully established. This can be inferred from the high levels of 'cultural' pollen including *Plantago* which is associated with disturbed habitats, particularly footpaths (e.g. Moore *et al.*, 1991, p.189), and Asteraceae pollen, much probably derived from *Taraxacum* spp. producing the very high 'lactuceae' representation, this taxon being particularly associated with grasslands subject to grazing (Behre, 1986). *Pteridium aquilinum* spores are also in greater abundance here than in the rest of the diagram and this species is associated with intermittently grazed pastures (Tansley, 1968, pp.181-183). The raised levels of *Corylus* type and *Salix* pollen compared to zone EB2 would also tend to support this interpretation, pastoral agriculture not involving the level of tree and shrub clearance associated with arable farming.

Zone EB2 commences at a ^{14}C calibrated date of ca. 1212 AD and continues for ca. 600 years until a ^{14}C cal. date of ca. 1807 AD (143 ± 145 years BP). A significant change in zone EB2 compared to EB1 is the continuous Poaceae $>40\text{ }\mu\text{m}$ curve, identified here as cereal pollen with a good degree of confidence, probably *Triticum* (see section 3.3.2) with a spike at 85 cm. When coupled with the drop in the pollen of Asteraceae (Lactuceae) and *Corylus* type, and the spores of *Pteridium* this points to a shift in the agricultural practices from pastoral to arable farming. The slight rise in *Plantago* and the appearance of *Rumex* and *Ranunculus* type pollen, normally associated with pastoral agriculture, is not consistent with an entirely arable land use suggesting a mix of land use along the linear catchment. The filling of the millpond with water inferred by the rapid rise in the pollen of pelagic species, particularly *Myriophyllum*, up to the middle of this zone supports the view of a predominantly arable land use in the vicinity of the millpond as a water-wheel for grinding the wheat would have been driven by water from the pond. Halliday (1959, p.137) records how a tenant farmer was fined 3d at Grampound in 1297 for evading the toll required of all the tenants who were duty bound to bring their grain to be ground at the mill. So the manorial mill was already an important source of revenue for the Cornish manor by the end of the 13th century.

Halliday (1959, p.117) uses the Domesday survey of 1086 to estimate a total population of Cornwall at that time of about 20,000. At this time the Cornish 'tinnars' (tin miners) were poorly organised and with labour obligations as 'villeins' to the landowners. What little tin they did produce was subject to manorial taxes. During the 12th century, however, the value of the tin industry of Cornwall for raising revenue was recognised and a 'Warden to the Stannaries' was appointed. By organising collection and standardising taxes the revenue was greatly increased. In 1201 King John extended this freeing up of the industry with the first charter to the Stannaries. The tinnars were allowed to dig and smelt tin 'at all times...and without hindrance from any man, everywhere in moors and in the fees of bishops, abbots and counts' (Halliday, 1959, p.127). They were even given their own Stannaries court to release them from their obligations to the manors. The consequent rapid expansion of the tin industry resulted in an estimated tripling of the population by the time that the Duchy of

Cornwall was established in 1337 and a 'corresponding pressure on the land and its produce' (Halliday, 1959, p.148). This chronology fits very closely to the land use changes inferred by the change in the pollen assemblage between zones EB1 and EB2 and the replacement of a partially minerogenic depositional environment with a wholly humic and plant derived one.

The other important feature of the local pollen assemblage between zones EB1 and EB2 is the change in the dominant Ericaceae species from *Calluna* to *Erica vagans*. That *E. vagans* has been present in the flora of the Lizard peninsula for many thousands of years is evidenced from pollen diagrams from older sediments reported in this study (Figs. 4.7, 4.11). Its current domination of much of the extant heathland of the Lizard appears to be correlated to the more intensive use of the land and the expansion of arable farming associated with the population expansion of the 13th and 14th centuries. Since it has been assumed that the pollen catchment includes the allochthonous pollen from Goonhilly Downs this infers that this area of upland heathland may also have been more intensively exploited from the start of the 13th century. The increase in *E. vagans* that results may therefore be attributed to its ability to recover more quickly following disturbance, recolonising burnt or ploughed land more rapidly than the previously dominant *Calluna vulgaris*.

Before leaving the EB1 to EB2 transition it is pertinent to identify that this also corresponds to the end of the Medieval Climate Anomaly (see section 1.7). This was a period of relative warmth that is usually considered to have ended by the start of the 14th century, to be replaced by the Little Ice Age. So Cornwall may have experienced a cooling climate after the pollen assemblage transition at EB1/EB2. There are no clear signs of this on the pollen diagram, however. Indeed the change from a pastoral to a mixed agricultural economy inferred by the pollen assemblage could be interpreted as being linked to a warming of the climate. This would also be inferred by the apparent rise of *E. vagans*, an Ericaceous species of Mediterranean origin, at the expense of the cold tolerant *Calluna vulgaris*.

With the exception of the spike in the cereal type large Poaceae grains at 85 cm, most probably resulting from a temporary increase in arable activity in the immediate vicinity of the pollen catchment area, zone EB2 shows very little change over approximately 600 years. During this period only the Black Death of 1348-49 AD (Halliday, 1959, p.156) might have

produced a reduction in population sufficient to affect the pollen assemblage. But Cornwall with its lack of large towns and remoteness from the rest of the British Isles appears to have been far less affected than elsewhere. It is not until the 19th century that population upheavals that resulted in changes in land use patterns were sufficient to be recorded in the pollen archives of the Erisey Barton mill pond.

The principal changes to the local pollen assemblage at the start of zone EB3 at 30 cm are the rise in *Pinus* pollen and changes in the herbaceous pollen, a fall in the large Poaceae and *Plantago* pollen and a rise in the remaining Poaceae, suggesting a reduction in arable agricultural and a reduction of the rural population. This is accompanied by a reducing humification of the depositional environment. The ¹⁴C calibrated date for the end of zone EB2 is 1807 AD. During the second half of the 19th century there was a significant depopulation in west Cornwall following the collapse of the mining industry in 1866. Halliday (1959) records a drop in the population of Gwennap parish from 11,000 in 1841 to 6,000 by 1881 for example. Whilst Erisey Barton is about 20 km south of the principal mining areas such as Gwennap this rapid depopulation would have had a significant impact on the land use of the area and would have been compounded by the agricultural depression of 1874 caused by the importing of cheap wheat from the American prairies (Halliday, 1959, p.335). The change in the pollen assemblage through this zone suggests that the effect of these two events was a shift back to pastoral farming and the establishment of the less labour intensive forest plantations.

Since the 19th century also encompasses the end of the Little Ice Age an indication of a warming climate might be expected in the pollen assemblage. As before, though, no clear climatic indicators are evident at this transition. It may be speculated that the cooling of the climate of the British Isles at the start of the LIA and its warming at the end corresponds closely with zone EB2 as a result of climate driven population movements. The increase in the population in the 13th century may have been the result of a push from the wetter, cooler east of the British Isles to the warmer climate of the southwest peninsula, as well as the pull of the newly liberated Stanneries. Similarly in the 19th century the warming of the eastern regions of the British Isles may have added to the incentives to leave the

economically declining west. However, there is no specific evidence for any of the pollen changes noted being related directly or indirectly to changes in climate.

The fall in Ericaceae pollen, the steepening rise in Poaceae pollen and the abundance of charcoal fragments, both $<50\ \mu\text{m}$ and $>50\ \mu\text{m}$ are all noticeable at the end of zone EB3 at 10 cm. The aquatic pollen has almost completely disappeared and the spore count indicates a much larger *Osmunda* population establishing itself along the edge of the stream running through the centre of the now sediment filled pond. An increase in *Salix* pollen is indicative of the willow carr establishing itself close to the old dam. These later observations can be confirmed by the current condition of the site, but the former is best explained by consideration of the final zone of the diagram.

Local pollen assemblage zone EB4 appears to take us into the modern era. *Abies* pollen forms a continuous curve indicating the introduction of exotics into the coniferous plantations, and a slight rise in the Ericaceae pollen at the expense of Poaceae pollen along with the consistently high charcoal count would be consistent with the establishment of modern heathland management practice on Goonhilly Downs.

5.3 Implications for the palaeoecology and environmental history of the Lizard peninsula

The vegetational reconstruction proposed here uses palynomorph proxies from three sites located in the central region of the Lizard peninsula plateau on, or just to the south of, Goonhilly Downs. Their archives overlap sufficiently for the vegetation to be reconstructed covering a period from approximately 8000 years BP to the present. Figure 5.1 at the start of this chapter provides a chronology of the five cores investigated.

The longest record comes from the Hendra site in a shallow valley that, at 54 m OD, is about 40 m below the Croft Pascoe site and 15 m below the Erisey Barton site. As such it provides a record of a slightly different climatic and edaphic environment, one that is currently agricultural land. The two sites on the higher ground are both currently

predominantly heathland that appears to have been established as a result of a contrasting environmental history, but in which the anthropogenic element may have been very significant.

5.3.1 Preanthropogenic ecology

From ca. 8000 to 5000 years BP the evidence from the HEN 1 and HEN 2 cores is of an area dominated by forest, initially *Betula/Pinus* with an early penetration of *Corylus* and some *Quercus*. The higher resolution HEN 2 diagram indicates a temporary opening of the canopy during this period which may well be attributable to Mesolithic people (Mellars, 1975). *Alnus* appears to be locally abundant following the end of this period at ca. 5000 years BP. The extent of this forested area cannot be confidently gauged from the evidence available here but it may be significant that there is only a trace of an herbaceous flora in the oldest parts of the HEN1/HEN2 diagrams (<10% of TLP), and most of this is attributable to very local flora. However, this increases to about 20% just before the rapid fall in tree pollen representation. This may infer that there was a pollen signal from the plateau even when the forest was near its maximum, implying that the very low herbaceous pollen representation at the base of the diagram indicates forest cover that extended over the plateau. Whatever the extent of the forest this investigation provides convincing evidence that, at the least, a large part of the Lizard Peninsula plateau was forested until about 5000 years BP and that the dominant species were birch and pine. Evidence for this has not previously been available (Hopkins, 1983).

5.3.2 Anthropogenic influences and their relationship to archaeology

At ca. 4000 years BP when the *Alnus* representation at the Hendra site is at its greatest but when there is also a strong *Quercus/Corylus* representation, the landscape 2 km to the northeast and 40 m higher at the Croft Pascoe site appears to be much more open. Although the *Quercus* curve during this period is similar at about 5% of the TLP at both sites, the *Corylus* representation is considerably lower at Croft Pascoe. The *Quercus* and *Betula* curves at Hendra have been suppressed by the very high *Alnus* count but at Croft Pascoe the

herbaceous pollen will have had a similar effect. The herbaceous pollen representation is the most striking difference between the two sites at this ^{14}C dated overlap at about 10% of TLP at Hendra compared to about 80% at Croft Pascoe. As described in section 5.2.3 the presence of cereal type large Poaceae pollen grains and pollen from 'weed' species such as *Plantago* at Croft Pascoe suggest that this is a Bronze Age anthropogenic landscape existing contemporaneously with the largely closed canopy forest a few kilometres to the south. This is in only partial agreement with the pollen evidence previously available from Bronze Age burial soils from Goonhilly and reported in section 1.4.3. In particular, Crabtree (in Hopkins, 1983) found higher tree and shrub pollen and lower heathland pollen with a trace of *Erica vagans* compared to modern soil, but no cereals. Smith (1984b) found no cereal or *E. vagans* pollen.

There is good archaeological evidence for a substantial Bronze Age presence in the area, however, as described in sections 1.4.3 and 1.5.3. Johnson (1980) and Smith (1987) describe the many Bronze Age burial mounds on Goonhilly although Johnson did not find much evidence for settlement. Christie (1986) speculates that the settlement in the area may have been associated with metal exploitation and both she and Jones (2008) identify the cooler, wetter period at the end of the Bronze Age and beginning of the Iron Age that resulted in the population moving to the lower regions, as has been established on Bodmin Moor and Dartmoor. These observations are all entirely consistent with the evidence presented here.

The apparent hiatus at ca. 2750 years BP in the Croft Pascoe diagram cuts off this line of evidence, but the disappearance of the cereal type large Poaceae pollen and the slight rise in both (small) Poaceae and *Corylus* (type) pollen representation suggests that the land use was changing just before this point.

At some time after ca. 4383 years BP the Hendra diagram indicates the removal of the closed forest canopy and its replacement by ca. 2230 years BP with an anthropogenic landscape. This could have been the work of Bronze Age or Iron Age people and there is good evidence for the significant presence of both on the peninsula (see sections 1.5.3 and

1.5.4 and above). Harrad (2004) has demonstrated the presence and importance of the gabbroic clay pottery industry on the Lizard that extended from the Bronze Age into the Iron Age and suggests that this may have been only one of a number of seasonal 'cottage industries' on the peninsula. Iron Age hillforts such as Trencrom near St. Ives (Silvester, 1979) and the Iron Age fields and courtyard houses of Penwith all point to a significant Iron Age presence in the region with the Iron Age hillfort at Carrick Luz east of Poldowrian on the Lizard Peninsula evidence of a local presence (OS Explorer 103, ref. SW 705165).

For ca. 1000 years the landscape in this region of the peninsula appears to have a strong heathland element with ericaceous pollen, particularly *Calluna*, being well represented. From ca. 1237 years BP (713 AD) a fall in the Ericaceae, further falls of the *Quercus* and *Corylus* (type) representation, and a rise in 'weed' and large Poaceae pollen suggest a more intensive use of the land. The relative stability of the landscape indicated by the Hendra pollen diagram from ca. 2230 calibrated years BP through zones H3 and H4 may be a reflection of the social stability of Cornwall during this period, isolated as it was from the many upheavals that beset much of the rest of the British Isles (Quinnell, 1986). The apparent intensification of land use from ca. 713 AD (1237 cal. years BP) may be related to the rapid growth of the population that was evident throughout Britain at this time (Salway, 1981).

From this point the high resolution Erisey Barton diagram provides the fullest evidence of the recent anthropogenic landscape. At its commencement about 400 years after the fall in the Ericaceae at Hendra the *Calluna* curve at Erisey Barton represents about 30% of the TLP but there are no cereal type large Poaceae grains. As at Hendra at about this time the tree and shrub representation in the pollen rain is negligible. Arable farming appears to commence at about 1200 AD (750 cal. years BP) which matches closely the first records of the Erisey family (Oaks, 1946). At this time arable farming appears to have been well established at the Hendra site 1.2 km to the south and 15 m below the Erisey Barton site. The top of the Croft Pascoe diagram that represents much of the same period as is represented by the Erisey Barton diagram, shows a very similar picture with low tree and shrub representation, the herbaceous pollen dominated by *Erica vagans* and *Plantago* spp. but, unlike the Erisey Barton diagram (and the Hendra diagram at this time), no cereal type large

Poaceae grains. The topmost section of the Erisey Barton diagram then takes us into the modern era with an increase in the *Pinus* pollen, the appearance of the exotic *Abies* pollen, an initially reduced but then increasing Ericaceae representation and greater evidence of fire. The final sample of the Croft Pascoe diagram at 40 cm appears to show the first elements of this period.

5.3.3 Significance for heathland composition and development, and the status of *Erica vagans*.

Although ericaceous species are present throughout the period represented by the three pollen archives they only have a continuous presence in the early anthropogenic landscapes. On the summit of the plateau, when evidence of arable farming disappears, heathland species dominate the vegetation. But 25 m below the summit, on the edge of the current Goonhilly Downs, evidence of arable farming appears alongside the heathland flora pollen, as it does during the first recorded 1000 years of farming 40 m below the summit. These observations may be exaggerated by allochthonous ericaceous pollen but the very low Ericaceae pollen representation at Hendra when the heathland flora on the plateau was well established suggests that this effect may be minimal. The fall in the heathland pollen signal on the lower slopes at Hendra occurred at about 700 AD (1250 BP) where it was displaced by an agricultural landscape, but there is little evidence of this happening either on the summit of the plateau or its periphery. The evidence here would therefore suggest that the development of heathland on the Lizard peninsula is dependent upon anthropogenic activity and is able to dominate the landscape if the intensity of farming diminishes. This is supported by the work of Smyth (1974), Crabtree (reported in Hopkins, 1983, p.39) and Balaam (1984) who all identified heathland pollen in Bronze Age buried soils, Smyth finding *Erica* spp. at 55% of the TLP in pre-barrow soils. The recent data (Forster et al., 2011) on the Late Devensian landscape (ca. 14000 years BP) just north of the Lizard at Carnmenellis, where Ericaceae represent about 30% of the TLP suggests that heathland was also present in the open landscape of the late glacial interstadial. Forster et al. also report from the same area evidence of a >50% Ericaceae pollen representation in a sample dated as Neolithic. It is also significant that on the lowest region of the peninsula represented here at Hendra, and

during the 20th century (Hopkins, 1983) heathland has been lost to agriculture, a situation that continues.

The current study thus adds weight to the suggestions of Grove *et al.* (2012) and the earlier evidence from buried soils on the Lizard (e.g. Smyth, 1974), that the development of lowland heathland here, as in most of southern England, is dependent upon anthropogenic agricultural activity both to enable it to establish and to provide the conditions to maintain it. The presence of Ericaceae pollen in the assemblage from the early pine/birch forests identified at Hendra, however, and the finding of late Devensian heathland at Carnmenellis (Forster *et al.*, 2011) and on Bodmin Moor (Brown, 1977), suggest that heathland will establish readily in open landscapes with low nutrient edaphic conditions. Heathland species are present in closed canopy woodlands and are able to expand rapidly when the canopy is opened. In some environments the podsolisation of soils following agricultural activity maybe a key factor, but this is unlikely to have been the case on the Lizard Peninsula with its slightly acidic and frequently waterlogged shallow soils.

The implications from this investigation for the origins of *Erica vagans* are dependant upon the very limited appearance of its pollen in the basal section of the Hendra core. The appearance of *E. vagans* type pollen in West Penwith in the early prehistoric era, and as far back as ca. 14000 years BP in the pollen assemblages from Carnmenellis (Forster *et al.*, 2011) argue against the possibility of an anthropogenic introduction. Its current endemic status on the peninsula despite its apparent earlier, more widespread distribution in West Cornwall, may be related to its close association with agricultural activity in marginal farming territory. This is indicated by its expansion at Erisey Barton with the arrival of arable farming, and the persistence of the heathland it has dominated alongside agriculture for almost 1,000 years. On the deeper, more fertile soils below the plateau, however, it was displaced by agriculture in the 7th century AD, an outcome that may have been repeated elsewhere in west Cornwall.

5.3.4 Summary

In summary the three sites investigated here provide a record of the changing landscape of the Lizard Peninsula plateau over at least 7,500 years. It appears that the preanthropogenic landscape, possibly of the whole of the plateau but more certainly of its lower slopes, was dominated initially by a birch/pine forest and later by an oak/hazel forest with locally abundant alder. By ca. 4000 years BP the landscape exhibited noticeable heterogeneity. The highest region of the plateau, the extant Goonhilly Downs, was an open landscape occupied by Bronze Age farmers, possibly after the clearance of forest, but the lower slopes were still heavily wooded. At ca. 3000 years BP at the earliest the plateau appears to have been abandoned by the farmers and by ca. 2230 years BP at the latest Bronze or Iron Age farmers had cleared the lower slopes of the peninsula. There is no evidence of a return to arable farming on the top of the plateau but there is evidence of increasing intensity of agriculture on the lower slopes during the Early Middle Ages (410-1066 AD, 1540-884 yrs BP) moving up to the edge of the current area of heathland by the Late Middle Ages, then retreating during the 19th century. Both the Hendra and the Croft Pascoe diagrams provide evidence for the importance of human intervention in the establishment and maintenance of the heathlands and the Erisey Barton diagram provides evidence for the unbroken presence of heathland on the plateau summit for at least 1000 years.

Chapter 6 CONCLUSIONS

This concluding chapter will consider the contribution of this research to our understanding of the environmental history of the southwest and in particular of Cornwall. It will also consider the implications for future heathland conservation practice on the Lizard Peninsula and relate the research finding to the aims set out in Chapter 1. Finally it will consider the possibilities for further palaeoecological research on the Lizard Peninsula.

6.1 Implications for the palaeoecology and environmental history of Cornwall and the Southwest

Building up a picture of the palaeoecology of Cornwall, and the far Southwest of England generally, has been much slower than in most of the rest of the British Isles. Caseldine (1980) points to the lack of glacial activity in the region resulting in the lack of over-deepened basins in which sediments or deep peats might develop. Forster *et al.* (2011) and Groves *et al.* (2012) describe how many of the pollen archives in Cornwall and the south of England that do exist have been disturbed by peat digging, tin streaming and other activities that have caused a discontinuity in the sequence of vegetational proxies, a problem identified in Cornwall by Burton and Chapman (1995) and Johnson *et al.* (2000). A further difficulty is presented by the soil conditions which in much of the region provide a poor environment for pollen preservation (Straker, 2011). Despite these problems, however, a more complete picture is developing to which the current study contributes.

To support the discussion two summary diagrams have been constructed (Fig. 6.1 and Fig 6.2). Figure 6.1 links the palaeoecological reconstructions resulting from this study to the available palaeoecological and archaeological data from western Cornwall and the Isles of Scilly. Figure 6.2 concentrates on the human impacts on the vegetation linking these with the available climatic and archaeological/historical data from western Cornwall.

Lizard Peninsula							HEATH project	Bodmin Moor	Isles of Scilly	Archaeology
Years BP (approx.) Culture	Hendra Mire HEN1/2	Croft Pascoe CPA1	Erisey Barton EBA2	Env. Agency (1999) French (1996)	Palaeosols Smyth (1974) Smith (1984b)		Straker, Forster et al (2011)	Brown (1977) Jones&Tinsley (2000)	Scaife (1984, 2006)	Berridge&Roberts, Mercer, Christie, Quinnel, (1986)
Present				<u>Porthleven</u> <u>Gunwalloe</u> open agricultural landscape			<u>West Penwith</u> heather, grass, hazel	↑ decreasing tree, increasing grass, cereals ↑		Historical period, see Fig. 6.2
Medieval	* disappearance of heathland	heathland with grass & plantain	heathland with pastoral & arable agriculture							
Rom-Brit ~ ~ ~ 2 000 Iron Age				<u>fall in trees</u> rise in grass, cereal	<u>Goonhilly</u> open landscape grass, sedge, plantain, heath, oak/hazel/alder		<u>West Penwith</u> forest clearance	↑ open landscape grass, cereals oak/hazel/alder ↑	large fall in trees, rise in *grass, cereals *rise in trees * fall in trees, rise in herbs with cereals	<u>Iron Age/Rom-Brit</u> stable Dumnonii culture, hill forts, courtyard houses, field systems <u>Bronze Age</u> copper & tin mining, export of ceramics, burial mounds (esp. Lizard), round houses, extensive trading – ‘Atlantic regional economic zone’
Bronze Age	open agricultural landscape with heathland	* disappearance of cereals		fall in trees rise in grass, cereal, bracken			<u>Lizard</u> forest clearance	↑ exposed short oaks/hazel sheltered tall oaks ↑		<u>Neolithic</u> hill fortifications, funerary monuments, stone circles, exports of artefacts to Devon
4 000		open landscape grass, cereals, heath, oak/hazel		oak/hazel/alder woodland						
Neolithic							<u>Carmmenellis</u> open landscape grass, sedge, heath, oak/hazel	↑ alder penetration ↑ <u>upland</u> grass, heath hillsides oak/elm/hazel woodland	* oak/elm/hazel/birch woodland	<u>Mesolithic</u> microliths and ‘retouched pieces’, coastal economy, temporary seasonal foraging sites inland
6 000	* rise of oak and (local) alder									
Mesolithic							<u>West Cornwall</u> oak/hazel woodland			
8 000	pine/birch/hazel forest									

Figure 6.1 Summary diagram linking the current Lizard Peninsula sites with other palaeoecological and archaeological data from western Cornwall and the Isles of Scilly (* dated events)

Years BP (AD/BC)	Period	Lizard Peninsula Palaeoecology	Climate	W. Cornwall Economic Activity	Cornwall History and Archaeology	References
Present	Recent Historical	<u>Erisey Barton</u> ¹ rise of pine, fir, grass, charcoal fall in <i>E.vagans</i> ----- <u>Erisey Barton</u> ¹ fall of hazel, dandelion, <i>Calluna</i> rise of cereals (<i>Triticum</i>), <i>E.vagans</i> <u>Croft Pascoe</u> ¹ <i>E.vagans</i> heathland, grass, plantain ----- <u>Erisey Barton</u> ¹ low tree, some hazel/willow grass, high dandelion, <i>Calluna</i> ----- <u>Hendra</u> ¹ fall in heather spp. ----- rise in cereals (<i>Triticum</i> , <i>Hordeum</i>), rise in plantain, dandelion, sedge ----- <u>Croft Pascoe</u> ¹ grass, sedge, Asteraceae, plantain, heath disappearance of cereals (3000BP) ----- <u>Hendra</u> ¹ severe fall in trees & ferns rise in grass, plantain, cereals, heathland <u>West coastal valleys</u> ³ fall in trees, rise in grass, cereal, bracken ----- <u>Goonhilly Downs</u> ^{1, 2} grass, sedge, Asteraceae, plantain, heath, cereals (<i>Hordeum</i>), high charcoal oak/hazel (birch/alder) <u>Hendra</u> ¹ oak/alder/hazel ferns <u>West coastal valleys</u> ³ oak/hazel/alder	↑ Little Ice Age ↓ Medieval Climate Anomaly (warmer) ⁸ ↓ climatic deterioration (colder, wetter) ⁷	1866 collapse of mining industry ¹⁰ ↑ growth of mining ¹⁰ 1337 estimated tripling of West Cornwall population ¹⁰ increase in tin mining ¹⁰ ----- reduction in mining with tin imports from Iberia ⁹ increasing pastoral & arable farming ¹⁰ ----- pastoral & arable farming ¹ continued trading of ceramics ⁵ amphorae imported from mainland Europe (oil & wine) ¹⁴ tin mining and trading ⁹ reduced contact with rest of BI ⁹ ----- copper and tin mining (inland & coastal loads) ⁴ Lizard production and trading in ceramics (later Bronze Age) ⁵ small scale mixed farming ¹¹ extensive trading along Atlantic seaboard (Ireland & Brittany [Armorica]) ⁶	1866 large population exodus, depopulation of farmland ¹⁰ 1856 peak of copper mining ¹⁰ 1850 start of mining exodus ¹⁰ 1348-9 The Black Death ¹⁰ 1297 manorial mill tolls ¹⁰ 1201 establishment of Stannaries ¹⁰ 1086 Domesday Cornish population estimate 20,000 ¹⁰ ----- 931 AD Saxon domination of Cornwall ¹⁰ ----- courtyard houses (west), oval houses (east) with associated field systems ¹³ 3 Roman forts excavated in east ⁹ limited Roman impact on Dumnonii of West Cornwall ⁹ hill forts ----- high concentration of burial mounds on Lizard ¹² Lizard gabbroic pottery found throughout Cornwall ⁵ 43 Cornish settlements excavated ¹¹ Armorican daggers and axes ⁶	1. current study 2. Smyth (1974), Smith (1984b) 3. French (1986), EA (1999) 4. Timberlake (1992) 5. Harrad (2004) 6. Christie (1986) 7. Charman (2010) 8. Trouet <i>et al.</i> (2009) 9. Quinnell (1986) 10. Halliday (1959) 11. Johnson (1980) 12. Smith (1984b) 13. Johnson & Rose (1982) 14. Saunders & Harris (1982)
500 BP (1450 AD)	Late Middle Ages					
1 000 BP (950 AD)	(Medieval)					
1500 BP (450 AD)	Early Middle Ages					
2 000 BP (50 BC)	Romano-British					
	Iron Age					
3 000 BP (1 000 BC)	Bronze Age					
4 000 BP (2 000 BC)						

Figure 6.2 Summary diagram linking Lizard palaeoecology with climate and human impacts from 4000 BP in western Cornwall

A Cornish and Isles of Scilly preanthropogenic landscape in coastal valleys and on some higher ground, of oak/hazel/birch forest with local alder and some elm and ash, is well established although the proportions of the predominant tree species does vary (e.g. Scaife, 1984; James & Guttman, 1992; Burton & Chapman, 1995; French, 1996, 1999; Environment Agency, 1999; Jones *et al.*, 2000; Forster *et al.*, 2011). A similar picture has been established for Dartmoor at ca. 7000 years BP (e.g. Caseldine & Hatton, 1993) although here the higher ground (>500 m) is thought to have been predominantly open heathland. This study shows that, on the Lizard Peninsula at least, this vegetation was preceded by a pine/birch forest up to ca. 5175 cal. years BP when it was replaced by alder and oak. While this ^{14}C date may be an under-estimate, a precedent for this has been established at Conford in Hampshire (Grove *et al.*, 2012) where the pine forest was replaced by alder and lime at 6050 cal. years BP. While birch is frequently found as an important component of the early post glacial landscape in Cornwall (e.g. Brown 1977, Forster *et al.*, 2011) the Hendra archive provides the first evidence for a period when the pre-anthropogenic landscape was dominated by pine, post dating the pine forests of much of the rest of the British Isles.

Bronze Age clearance and cultivation of the higher ground in Cornwall and the Isles of Scilly is also well established (e.g. Brown, 1977; Scaife, 1984; James & Guttman, 1992.; Burton & Charman, 1995; Jones *et al.*, 2000). In all these cases there is evidence of pastoral agriculture and in many cases arable farming is also indicated by the presence of cereal grains. Archaeological finds and the pollen record of buried Bronze Age soils (e.g. Smyth, 1974; Smith 1984b) have established a Bronze Age presence on the Lizard. The Croft Pascoe pollen diagram supports this and, for the first time, provides evidence of arable farming. The Lizard peninsula therefore conforms to the evidence for Bronze Age agriculture that we have from much of the rest of Cornwall.

From the Iron Ages to the modern era the evidence from elsewhere in Cornwall is rather patchy. Charman (2010) notes evidence for cooler, wetter conditions at ca. 2800-2700 cal. years BP in the British Isles and Brown (1977) uses the evidence from Bodmin Moor to estimate this at ca. 2500 years BP. Tinsley shows that between ca. 3600 and 2100 cal. years

BP there is a significant drop in tree pollen in her diagram from the Porthleven excavations (Environment Agency, 1999). In the current study the end of arable farming on the Lizard plateau at Croft Pascoe appears to occur a few hundred years before these estimates for climate deterioration but the truncation of the archive soon after this event, close to 2788 ± 48 cal. years BP, makes it difficult to co-ordinate with dates from elsewhere in the region. However, the Hendra diagram indicates that by 2230 ± 82 cal. years BP the land on the lower regions of the plateau had been cleared and farming, including arable, was taking place. The palynological evidence from the Croft Pascoe and Hendra sites therefore appears to broadly co-ordinate with evidence from elsewhere in Cornwall of a change in land use between ca. 2100 and 2800 years BP possibly associated with the development of a wetter and cooler climate.

The Bronze Age agricultural landscape on the high ground of the Lizard Peninsula mirrors that of Dartmoor where it is characterised by the boundaries known as 'reaves' (e.g. Fleming, 1994). Here also the high ground was abandoned, possibly due to a climatic shift to cooler and/or wetter conditions ca. 3200 years BP (Amesbury *et al.*, 2008). This is several hundred years earlier than appears to be the case in Cornwall. Amesbury *et al.* point out that other socio-economic factors may have played a role in this retreat and the possible lack of synchronicity of these events in the southwest would tend to support the view that climate may be only part of the explanation. The dating of these abandonment events both in Cornwall and Dartmoor remains uncertain, however, so caution should be exercised in drawing conclusions from them.

Through the Iron Age and into the historical period the evidence from other sites in Cornwall is severely limited. This has resulted from a lack of radiocarbon dates and apparent discontinuities in most of the pollen diagrams so far produced. The sequence from De Lank mire on the northwest edge of Bodmin Moor, (Jones *et al.*, 2000), is described in section 1.4.2. It appears to show an Iron Age to Medieval landscape with a fluctuating extent of cereal cultivation and grazing. The archaeological evidence also points to population fluctuations and it is suggested that these may have resulted from a changing climate in an agriculturally marginal area. The Hendra diagram appears to show a continuous

palynomorph record from at least 2230 ± 82 cal. years BP with consistent levels of pastoral and arable farming until the 19th century, marked by the appearance of *Abies* pollen. The only significant change throughout this period is the suppression of the *Ericaceae* and *Pteridium aquilinum* curves at ca. 1237 ± 61 cal. years BP. It is assumed that this resulted from an intensification of the agricultural activity on the peninsula. A period of largely unbroken agricultural activity is also evident from the edge of Goonhilly Downs at the Erisey Barton site from ca. cal. 1212 AD. The current study therefore adds an important new dimension to our knowledge of Cornish palaeoecology with these two apparently unbroken records covering a period from the Iron Age to the present. The overriding impression they give is of a landscape largely unaffected by major climatic or population shifts, but with the higher resolution diagram from the more marginal agricultural environment at Erisey Barton indicating changes in land use that appear to coincide with significant changes in the local economy. This is in contrast to the fluctuating land use evident from De Lank.

6.2 Implications for heathland conservation on the Lizard Peninsula

Only one of the two areas of heathland on the Lizard Peninsula is represented in this research. The heathland history of Lizard Downs is yet to be described but the current study sheds light on the history of the heathland on Goonhilly Downs. A clear indication from both the Erisey Barton and the Croft Pascoe diagrams is that Ericaceous heathland has dominated the area for at least 850 years and possibly since Bronze Age farmers abandoned the plateau almost 3,000 years ago. Initially the heathland was dominated by *Calluna vulgaris* but *Erica vagans* has always been present and became the dominant species ca. 800 years ago. The heathland has coexisted with agriculture, with pollen of both landscape types appearing in the pollen assemblages from both the edge of the Downs and downslope to the south in an area now dominated by pastoral agriculture. Ericaceous pollen largely disappeared from the pollen assemblage of the lower slopes ca. 1,250 years ago (ca. 700 AD).

The conservation practices currently in place maintaining the heathland of Goonhilly Downs are clearly maintaining a very longstanding 'natural', probably anthropogenic landscape and

the loss of heathland on the lower slopes indicate that the heathland is vulnerable to increased agricultural exploitation of the land. The fall in the Ericaceous pollen during the 19th century to 13% of TLP indicated on the Erisey Barton diagram might well be investigated further, particularly since its recovery to 36% today has not returned the Ericaceous pollen back to its peak in the 18th century of 57%. A concentration diagram will be required to determine whether these changes represent real changes in the Ericaceous pollen production.

Possibly the most valuable finding for the information of conservation practice is the rise on the Erisey Barton diagram of *E. vagans* at the expense of *Calluna* pollen at ca. 1200 AD (738±46 cal. yrs BP), apparently in response to the increased agricultural exploitation of the land in the vicinity. This needs to be considered alongside the domination of *E. vagans* pollen in the Croft Pascoe diagram from ca. 500 years ago, so the completion of this diagram to include the top 40 cm of the archive will also contribute to our understanding of this change. The suggestion is, however, that the extant *E. vagans* dominated heathland of Goonhilly Downs is maintained by anthropogenic activity and it could revert to a *Calluna* dominated heathland as a result of changes in the management regime. The Natural England warden on the Lizard Peninsula believes that *E. vagans* will thrive at the expense of *Calluna* and *E. tetralix* when the loess is penetrated by agricultural activity or other soil disturbance (Ray Lawman, 19.02.13 pers. com.) so transforming Short Heath to Tall Heath. This interpretation would suggest that the soil changes that enable *E. vagans* to dominate are unlikely to be reversed.

In order to fully utilise the current findings for the information of conservation practice on Goonhilly Downs some further analysis is required. The clear message, however, is that this area of heathland represents an ancient landscape whose conservation should remain a very high priority on the basis of its aesthetic, biodiversity and historical value.

6.3 Summary of thesis aims and research findings

Three research aims were posed at the outset of this research. All have subsequently been addressed but, inevitably, questions still remain in all cases. The research aims will be considered one by one.

- i. To determine the nature of the preanthropogenic landscape on the Lizard Peninsula plateau. More specifically to establish whether or not the plateau was forested and if so the nature of the forest.

Only the Hendra mire site has sediments old enough to address this question and with a basal ^{14}C cal. age of 7489 ± 64 years BP they predate the Neolithic Age, and the elm decline of ca. 5000 years BP in much of the rest of the British Isles. At the very base the pollen assemblage is dominated by *Betula* and *Pinus* with some *Corylus* type, and the spores of *Pteropsida* spp. There is very little pollen of herbaceous origin. This points to a closed canopy forest of birch and pine with an understory of hazel and a ground flora dominated by ferns. The Hendra site is 54 m below the summit of the Lizard plateau, however, so it cannot be assumed that this forest extended across the whole of the peninsula. Nevertheless, an important step has been taken in our knowledge of the preanthropogenic landscape of the Lizard Peninsula although much is still to be learnt about the origins and extent of this forested landscape.

- ii. To trace the origins and development of the heathland vegetation and to determine the extent of the human contribution to this development.

The presence of an Ericaceae dominated heathland is evident in the pollen diagrams from all three sites investigated. Its earliest occurrence is at the Croft Pascoe site where all three Ericaceous groups (*Calluna*, *Erica vagans* and Ericaceae undif.) and the heathland characteristic species *Sanguisorba officinalis* appear within an apparently anthropogenic Bronze Age landscape of ca. 4152 ± 254 cal. years BP. There is no evidence of the origin of this heathland flora and the hiatus in the pollen archive at ca. 2788 ± 48 cal. years BP means that its development into the dominant heathland flora of the historical period cannot be traced.

The pollen diagram from the Hendra site has a pollen assemblage with no continuous presence of Ericaceous spp. from its base at 7489 ± 64 cal. years BP until the apparent hiatus at ca. 4383 ± 137 cal. years BP. At or just above the putative hiatus at ca. 2230 ± 82 cal. years

BP a significant heathland flora is indicated but this has severely diminished by ca. 1237±61 cal. years BP. The surface samples from this site show only a minimal Ericaceae pollen signal, probably from Goonhilly Downs to the north, so it is safe to assume that a heathland flora was present in the vicinity of the Hendra mire for at least 1,000 years, alongside the agricultural landscape. The near disappearance of this heathland pollen assemblage appears to coincide with an increase in the arable agriculture in particular, and there are no signs of it recovering to the present day.

The Erisey Barton site shows a continuous presence of Ericaceae species throughout its ca. 850 year archive. This exists alongside evidence of agricultural activity through the whole of this period. Of particular significance is the original domination of the Ericaceae pollen by *Calluna*, also evident on the Hendra mire and Croft Pascoe diagrams, but its replacement by *Erica vagans* as the dominant species at ca. 1212 AD (738±46 cal. years BP) at the point where changes in other species indicate the establishment of arable farming in the vicinity. This domination by *E. vagans* continues to the present and is also evident at the top of the Croft Pascoe diagram over at least the last 500 years.

In summary this research indicates that heathland, to a lesser or greater extent, has been a significant part of the Lizard Peninsula landscape since the early Bronze Age at the latest. It existed alongside agricultural activity both on the summit of the plateau during the Bronze Age and on the lower slopes during the Iron Age and the historical period. It appears to have been suppressed by an increasing intensity of agriculture on the lower slopes but with the abandonment of agriculture on the plateau it became the dominant vegetation type. At Croft Pascoe and on the edge of Goonhilly Downs at Erisey Barton the heathland pollen has dominated the pollen assemblage for up to a millennium. The work of Forster *et al.* (2011) indicates the presence of a similar heathland flora in the late Devensian landscape at Carnmenellis and in the current study there is equivocal evidence that Ericaceous pollen was present in the pollen assemblage from the early forests. So heathland can be seen to be the climax vegetation of the region when forests are suppressed either by the climate or by the anthropogenic activities of grazing and burning. There is insufficient evidence to suggest that its establishment is also dependent on the nutrient depletion and podsolisation of the

soils following their use for arable farming. Heathland appears at the Hendra site following the removal of the forest and this area currently has deeper and more nutrient rich brown earth soils. However, there is a possibility that these soils were 'improved' by manuring at the time of the suppression of the heathland flora.

- iii. To gather evidence of the history of the endemic Ericaceae *Erica vagans* on the peninsula in order to inform the debate as to the origins of this species in the post Devensian recolonisation of the area.

This has been a very interesting question involving, as it does, the complex issue of the post Devensian recolonisation of the British Isles. A review of the literature suggests that the current flora and fauna of the islands arrived by many and varied routes and at different times. The Lusitanian element of the British and Irish flora seems to be no exception and no one possible route is likely to be a satisfactory explanation for all the various species that have been included in this grouping. This study has found some, rather limited (3 pollen grains), evidence for the possible presence of *E. vagans* pollen in the preanthropogenic landscape of the Lizard Peninsula. This has been reinforced by its discovery in the late glacial interstadial at Carmenellis, just to the north of the Lizard Peninsula, and in West Penwith, where it is not found today, at ca. 1000 AD (950 BP) (Forster *et al.* 2011). This most recent study for the HEATH project suggests, therefore, that *E. vagans* migrated to its current location on the Lizard Peninsula among the very earliest of the post glacial colonizers and, until recently, has been far more widespread in Cornwall. Scaife (1984, 2006) and recent work by Perez (Marta Perez, 01.10.12, pers. com.) have indicated that *E. vagans* never formed part of the flora of the Isles of Scilly. This study confirms that it has formed a significant part of the heathland flora of the post anthropogenic landscape of the Lizard Peninsula since the Bronze Age, and for the most recent 800 years at least its pollen has dominated the Ericaceae pollen in the vicinity of the two study sites on Goonhilly Downs.

The mechanism by which *E. vagans* arrived in Cornwall is still open to debate but its very early post glacial arrival reduces the possibility of an anthropogenic introduction and other

evidence, particularly from DNA (e.g. Kingston & Waldren, 2006; Oppenheimer, 2006) tends to support the view that it migrated from its base in the Iberian Peninsula along the now drowned eastern seaboard of the late glacial European continent.

6.4 Suggestions for further work

The ultimate aim of Holocene vegetational history studies on the Lizard Peninsula must be to create a chronology of landscape changes from the late glacial to the present that covers the broad range of climatic and edaphic zones. This study, and those of the recent HEATH project (Forster *et al.*, 2011), have extended our knowledge of the palaeoecology of western Cornwall significantly but, as with previous work in the area, the data is fragmentary. The palynomorph archives investigated here have been short, discontinuous or both and it is likely that further studies will encounter similar constraints. But there is every reason to believe that many further short palynomorph archives exist which, collectively, may produce a relatively continuous chronology. The archives investigated here still have more information to reveal, particularly the Hendra mire site with its archive extending back at least 7500 years BP and possibly a lot further. The apparent discontinuities in the record of both the Hendra and the Croft Pascoe cores, however, will require the analysis of further sediment archives on the Lizard Peninsula to fill in the gaps.

One of the principal research findings of this study has been the discovery of the birch/pine forest in the preanthropogenic landscape of the Peninsula. Extending this back, possibly to its origins in the Late Devensian/Early Holocene, should therefore have a very high priority for further work.

The HEN1 and HEN2 cores were collected before a more complete survey of the site had been completed and a maximum depth of sediment of only 125 cm was found. Following a systematic survey in which the depth was measured across three transects a further 55 cm depth of sediment was discovered closer to the drainage channel (see Figs. 2.10 and 2.11). A 10 cm core was collected from this site, HEN3, but there was insufficient time for a palynological analysis. A ^{14}C date of wood fragments found at 160 cm indicate an age of

3972±32 cal. years BP, considerably younger than the 7489±64 cal. years BP recorded for bulk material collected at 120 cm in the centre of the mire. The interpretation of the data in Chapter 5 has assumed this date as being contemporaneous with the sediments in which the fragments were found but the possibility that these were root fragments cannot be discounted. To investigate the validity of this ^{14}C date from the HEN3 core a palynological investigation of the sediments over the basal 60 cm of the core should be carried out. Should the 160 cm sample have a pollen assemblage with a very high *Alnus* pollen count as suspected (see section 5.1), this will support the ^{14}C dating of these sediments. Deeper sediments in the centre of the mire revealed by the transects could then be investigated to extend the palynomorph record back into the birch/pine forest. Should the HEN3 ^{14}C date not be verified by the pollen assemblage a diagram from the base of this core has the potential to extend the palynological record considerably.

The transect data from the Croft Pascoe site (Fig. 2.8, Appendix VII) does not indicate any sediments deeper than the 85 cm CPAI core so there is unlikely to be a longer archive within this feature. The possibility of the feature being of Bronze Age or even Late Neolithic origin and the suggestion that it may be a surficial lode needs to be investigated further. Andy James of the Cornwall Archaeology Unit suggested that this could be investigated further by an analysis of heavy metals within the sediments (Andy James, 8.01.13, pers. com.). Similar studies in Southwest England have been carried out by West *et al.* (1997) and Thorndycraft *et al.* (2004). The top 40 cm of the CPAI core still requires palynological analysis to support the Erisey Barton data in elucidating the recent (18th to 20th century) vegetational history of Goonhilly Downs.

Further analysis of the data already collected at all three sites will be required to prepare the material for publication. In this study only the pollen analysis of the short, basal 30 cm of the HEN2 core has included a concentration diagram. Further concentration diagrams need to be produced for the three remaining cores analysed here, HEN1, CPAI and EBA2. This will help support the interpretation of the percentage diagrams. In addition the subjective analysis provided here will be supported by the more objective, quantitative analysis of the

pollen data provided by the Multiple Scenario Approach software suite of Bunting and Middleton (2009).

In the longer term the priorities should be to investigate further sites on Lizard Downs with a view to discovering viable palynomorph archives of this important heathland area. Further sites on Goonhilly Downs will also be required to provide more information on the extent of the preanthropogenic forest and to fill in the gaps in the pollen record associated with the transitions from forest to agriculture and from Bronze Age farming to heathland. The loss of sediment at these horizons in the HENI and CPAI archives has left these aspects of the vegetational history uncertain. Of particular interest would be the preanthropogenic landscape of the high point of the plateau on Goonhilly Downs. There is equivocal evidence here that this area was being farmed in the Bronze Age before clearance and farming commenced in the vicinity of the Hendra mire, 50 m below and 4 km to the south. If this is the case then the nature of the preagricultural landscape could be of great significance in understanding why this currently non agricultural area should have been the focus for early agriculturalists.

The macrofossils of the Hendra mire sediments have been analysed here and there is further scope for the use of these as proxies for climatic and land use changes within the Croft Pascoe and Erisey Barton sediments also. The possibilities for the presence of archives of other climatic and environmental proxies should also be considered. Straker (2011) points out that the calcareous shells of molluscs, ostracods and foraminifera are particularly vulnerable to acid soils such as those of the Lizard but that they may survive where sand blow has affected the soils. This could be a significant factor particularly along the western coast of the peninsula. The 'Miscellaneous peat soils' of the Lizard soil survey (Staines, 1984) have been investigated but possible further sites on both Lizard Downs but more particularly Goonhilly Downs have been identified by a project archaeologist who walked the area for the Historical Environmental Service in 2006 (Sean Taylor, 26.09.06, pers. com.). These have been recorded on the OS map and will be individually checked.

It is very unlikely that there will be a single major 'breakthrough' in our understanding of the palaeoenvironments of the Lizard Peninsula in the form of a single unbroken chronology

from the late glacial to the present. However, the incremental developments in our knowledge represented by this study will continue and a much broader picture will emerge over time.

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Appendix I

- Laboratory Protocols pp. i – xii
- Pollen count sheet
- Laboratory preparation checklist
- Charcoal fragment count sheet
- Charcoal frequency calculation sheet

UNIVERSITY OF CAMBRIDGE
DEPARTMENT OF GEOGRAPHY

POLLEN PREPARATION PROTOCOL (V. 1-1)

Wear a lab coat, latex or vinyl gloves and have a pair of safety goggles accessible.

Samples are typically, between 0.5 and 2 cm³ and can be sampled using a calibrated volumetric sampler or using water displacement in a 5 cm³ measuring cylinder. These should be placed into 50 ml plastic centrifuge tubes (small tubes can be used if samples are particularly small).

To quantify the concentration of pollen within the samples an exotic spike can be added, 1-3 lycopodium tablets depending on the nature of the sediment ie. 3 if lots of pollen likely. A ratio of 1:1, or 1:2 is desirable for statistical accuracy, although 1:5 is acceptable. Remember to note the batch number of the lycopodium tablets which relates to the concentrations of spores contained within the tablets which is used in the later calculations.

1. Hot 7% HCl, heat up water bath in fume cupboard to ~90°C (takes 20-30 minutes). Fill tubes 2/3 full with HCl and place in the water bath for 20-30 minutes so HCl dissolves carbonate, there may be violent reaction a drop of methylated spirits can be used to break surface tension and stop samples foaming. Stir occasionally with glass rods (one for each tube). This acidifies the samples to pH1.

If samples are very calcareous it may be necessary to remove carbonate using a small amount of concentrated HCl.

Balance and centrifuge, large tubes 3000 rpm/5 minutes, small tubes 3000 rpm/3 minutes.

2. Wash H₂O, decant off the "yellow" or "brown" clear liquid supernatant in one fluid movement from tubes into a large waste beaker (the contents of the waste beaker can be emptied down the sink and washed away with water), solid residue should be left in the bottom of the tubes. Whirlimix and top up with deionised water, ensure that all the sample is mobilised, use a glass rod if necessary.

Balance and Spin

Whilst this is spinning prepare sieves ie. Flame with gas burner (using tongs) and quench in water, also prepare funnels and second batch of tubes with labels.

3. Hot 10% NaOH, decant and whirlimix. Fill tubes 1/3 to 1/2 full with NaOH. This takes the pH up to alkaline (pH14) taking humic acids into solution. Place in water bath for 2-4 minutes. **Do not** whirlimix or decant.
4. Sieve, put second batch of tubes into a rack with funnels and sieves. Sieving should be carried out wearing safety glasses as even a small amount of NaOH can seriously damage your eyes.

Pour each sample through the sieves, wash through using deionised water (a nozzle restrictor may be useful to increase the pressure of water and restrict the amount used). Wash through sieve thoroughly using the 'corner method' if you want i.e. working across the sieve from top to bottom and then left to right.

Place used tubes, sieves and funnels into sink after use. Difficult samples may be worked through, the mesh using a clean gloved finger or glass rod (care must be taken not to damage the sieve mesh). Alternatively, a few water washes prior to sieving will remove humic material, dilute the NaOH so making sieving safer.

5. Wash H₂O, same procedure as 2, repeat until the liquid that is being decanted off is clear (this usually takes 5-6 washes, but if you are lucky up to ~16!!). This removes humic acids (brown) and clays (usually grey). Sticky samples can be difficult to whirlmix and should be stirred with a glass rod, very clay rich samples may benefit from the use of 4% sodium pyrophosphate to help break the electrostatic bonds (placing in the water bath for ~10 minutes will further aid this process), a couple of water washes may be required to fully remove particles.

The metal Sieves should be washed thoroughly in hot water with detergent, these are not to be washed in Decon, which is corrosive. Funnels should be washed in detergent and then placed in a bowl containing Decon (see washing up protocol).

6. Wash 7% HCl, same as 2, except using a smaller amount of HCl instead of H₂O. Only do this once. This is to acidify the samples before HF, assist the action of HF on samples and to make sure there is no residual carbonate.
7. HF cold/hot, if inexperienced **GET SOMEONE TO WATCH YOU. VERY DANGEROUS!** Wear long brown rubber apron, latex or vinyl gloves, black rubber gloves and full face mask. Prepare a large beaker containing a saturated solution of sodium carbonate (which neutralises HF) in the fume cupboard. Make sure that you know the location of all the related safety equipment and the procedure in case of a spill;

Calcium gluconate tablets to be taken if you come into contact with HF - in fridge.

Calcium gluconate gel to take to hospital for application to and injection under HF burns - in fridge.

Slaked lime to neutralise large spills of HF - in large canister.

The water hose in case you become contaminated, in which case remove all contaminated clothing and hose yourself down for 15 minutes with cold running water.

All work **MUST** be carried out in the fume cupboard. Open sash slowly as a brief reversal of air flow can be created which draw fumes out into the lab if opened quickly.

Hot - Carefully pour HF into each tube 1/2 - 2/3 full and leave for ~2 hours in the 90°C bath in the fume cupboard. Wash everything well in sodium carbonate. Particularly silicate rich samples may require multiple HF's or even leaving overnight **with the water heater off, the fan on and good labelling.**

Cold - Alternatively, samples can be left well labelled and with tube caps on at the back of the fume cupboard for a longer period of time, it is best to leave the fan on during this period.

After this time put caps on tubes before removing them from the water bath. Balance (add water into tube containers to balance) centrifuge with caps on. Remove tube caps and decant carefully down the FUME CUPBOARD sink. Dip the whole tube into the saturated Sodium Carbonate solution to remove drips of HF from the tube. Do not allow any sodium carbonate into the tube.

Wipe down the floor of the fume cupboard with cloth soaked in Sodium Carbonate solution, in case of any unnoticed splashes.

HF removes silicates from the samples. This can also be achieved using density separation which floats off organic material leaving the silicate minerals behind.

8. Hot 7% HCl, place into water bath for 20-30 minutes to remove silicate residues and fluorosilicates. Heating increases the solubility.

10% HNO₃, dilute Nitric Acid may be required at this stage to remove sulphides. Follow procedure as 2.

9. Wash H₂O, same procedure as 2. Transfer to small tubes.

10. Wash CH₃COOH, Concentrated (glacial) Acetic acid (smells of vinegar). Same procedure as 2 except use CH₃COOH instead of water. However, when decanting pour waste down the sink in the fume cupboard when centrifuging, use tube caps if necessary. This is used to remove water so that acetolysis can be carried out.

11. Acetolysis, use green nitrile gloves. This mixture reacts exothermically (produces heat) and can be both violent and dangerous, especially when it comes into contact with water.

To make up the acetolysis mixture combine 9 parts of Acetic Anhydride (ie. 45 ml) with 1 part of Conc. sulphuric acid (ie. 5 ml) (pour into a smaller beaker first as the bottle is unwieldy) in a measuring cylinder. Place 5 ml of the mixture into each tube, working in the fume cupboard, and incubate in water bath for 3 minutes.

This procedure removes cellulose and polysaccharides from samples by oxidation.

12. Wash CH₃COOH, remove from water bath and top up with Acetic acid to cool and stop the acetolysis reaction and balance. Spin and decant down the sink in the fume cupboard.

13. Wash H₂O, same procedure as 2. Meanwhile put the wash bottle of TBA into the the water bath to melt. **Loosen top to avoid explosion due to a pressure build up!**

14. Wash ~1% NaOH, after decanting, whirlimix and then add a squirt of 10% NaOH, whirlimix again and top up with H₂O. Balance, spin and decant down sink or into a beaker with water in it. Whirlimix.

The purpose of this stage is to take the pH from slightly acid to slightly alkaline. (Safranin turns blue in acidic solutions!!).

15. Wash H₂O, same procedure as 2.

16. Wash H₂O + 0.2% aqueous safranin, for wash same procedure as 2, but add 1-4 drops of dye (depending on sample), whirlimix, top up with H₂O, balance, spin and decant.

17. Wash TBA, remove warmed TBA from the water bath and 1/2 fill tubes best done in the fume cupboard. Be careful not to get the TBA on you as it is toxic or breath the fumes. Balance (top up with TBA), spin and decant into a beaker with water in it. Whirlimix. TBA removes water from samples so silicone fluid/oil can be added, decant down fume cupboard sink.
18. Vial of remainder, label vials (No. three times top and bottom, depth, site and sample no.) Put a small amount of TBA into TUBE 1 (not vial 1) and whirlimix as normal. Then pour into VIAL 1, repeat until all the residue is in vial 1. Once completed for all the samples place the vials into the centrifuge 'tube holders' using tweezers and spin as normal. Place tubes into the sink for washing.

Decant vials into the waste beaker with water in it (to control TBA fumes) and add silicon oil (1-6 drops roughly equal to the quantity of residue) to the tubes with a disposable pipette or cocktail stick. Mix well with a cocktail stick leaving one in each vial, place safely in a beaker lined with tissue and cover to prevent contamination. The TBA will evaporate off over a couple of days, the samples need to be checked and stirred to make sure that they have not dried out and stirred during this period. Then you will be able to make slides and begin enjoying counting pollen!!!

Compiled by William Gosling with the assistance of Ian Lawson, Katy Roucoux and Steve Boreham.

WASHING UP PROTOCOL

All equipment that has come into contact with pollen, except the sieves should be washed in this way.

1. Wash and scrub vigorously in normal detergent and warm water, then placed under running water.
2. Transfer to a bowl containing deionised water and 50-100 ml of Decon 90 (Alkaline and will burn skin). Soak for 12-48 hours.
3. Rinse in deionised water and fully immerse in a 1% HCl solution (cover bottom of bowl with 7% HCl and half fill with deionised water).
4. Stack in drying basket and place in ~50°C in glassware drying oven. Put your tubes away!!!!

HYDROFLUORIC ACID AND YOU!

Hydrofluoric acid is corrosive. As a gas it is highly irritating to the eyes and the respiratory tract. In solution it can cause severe burns. If you get it on your skin you may not feel the pain at once.

PROTECTION

- **ALWAYS** use the protection provided.
- **ALWAYS** wash your gloves and other impervious clothing before you remove them.
- **TEST** gloves for pinholes by filling them with water, before drying and putting them away ready to use again.
- **ALWAYS** wash your hands before you leave the work area.

SPILLAGES

- Spillages on tools, bench - neutralise with slaked lime.
- The contaminated area must be hosed with plenty of water.
- Spillages on clothing - neutralise with sodium bicarbonate solution.

FIRST AID

1. Gassing

- Remove the casualty fresh air.
- If necessary, resuscitate the casualty.
- Send to Accident and Emergency Unit.

2. Skin

- Remove contaminated clothing (NB: protect your hands with gloves).
- Flood skin with clean cool water to remove acid. Send to Accident and Emergency Unit without delay, continuing the following during transit. Apply calcium gluconate gel on and around the affected area and massage it continuously until pain is relieved. This will take at least 15 minutes. Cover area with dressing soaked in gel. Bandage lightly.

3. Eyes

- Irrigate with clean cool water for at least 20 minutes. This can be continued during transit to hospital.
- Send to Accident and Emergency Unit or local eye hospital.
- In all cases inform hospital of the cause of the injury.
- Report splashes on skin and eyes to supervisor/employer.

FIRST-AID TRAINING

It is the responsibility of your employer to ensure that there is an adequate number of employees on site trained in appropriate first-aid procedures.

Training should be given by organisations approved by HSE. If you have an occupational health department, the doctor or nurse will be able to advise you on how to carry out the different procedures in your workplace.

LEGAL REQUIREMENTS

The Control of Substances Hazardous to Health (COSHH) Regulations 1988 apply to hydrofluoric acid - see Approved Code of Practice COP29, ***Control of substances hazardous to health***, available from HMSO (ISBN 0 11 885468 2).

The Health and Safety (First Aid) Regulations 1981 apply to all aspects of first aid at work - see Approved Code of Practice COP42

First aid at work, available from HMSO (ISBN 0 11 885536 0).

REVISED ACETOLYSIS

(c/o CHARLES TURNER, 2009)

The revised preparation procedure, which I think we should try is as follows:-

After your usual HF, followed by HCl (or flotation if you are using that)

Instead of the Erdtman acetolysis, two procedures -

1. **"Godwin Acetolysis"**

For a set of 8 samples, prepare the solution 80cc glacial acetic acid + 4cc conc. sulphuric acid and boil in water bath for 30 minutes. Do **NOT** use acetic anhydride!

2. **"Oxidation"**

Here the mixture for 8 samples is - 64cc glacial acetic acid + 36cc saturated solution of sodium chlorate + 6cc conc. sulphuric acid.

Stand cold in fume cupboard for up to 12 hours, less organic samples can be ready after 4 hours but I suspect Geoff's samples are pretty organic. No need for much washing, just top up with water and centrifuge between the two procedures.

After oxidation wash well until supernatant clear - add a few drops of NaOH before staining etc.

I sometimes briefly reheat samples in 7% NaOH after an Erdtman Acetolysis, which can get rid of more residual organic gunk (and I have suggested that Geoff takes some samples he has counted and still has sufficient residues back through TBA and tries this), but this is probably not necessary here after this oxidation procedure.

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POLLEN EXTRACTION : SEDIMENT PREPARATION USING HF

Mark off the steps on the appropriate sediment record preparation sheet:

Using the 0.5 cm³ tube sampler measure 1 cm³ of each sample into the centrifuge tubes.

Note the wet weight then place in the oven at 60 degrees overnight.

Note the dry weight.

Place samples in centrifuge tubes in metal rack.

Add marker pollen tablets x 1 (depends on sample amount).

Add 10% HCl acid, about 1 inch in tube bottom (working in the fume cupboard all the time).

Frothing will occur, stir with plastic spatula to keep under control (NB: always mix well in the tubes).

Place black rubber caps onto tubes (do not mix caps).

Leave for 20 minutes, add distilled water, stir and centrifuge for 10 minutes at 3100 rpm.

Decant off the acid (supernatant) into the sink with tap running (NB: the residue may or may not be clumped in the tube bottom).

Add 40% Hydrofluoric acid to tubes (as for HCl) leave for 20 minutes.

Top up tubes with distilled water, stir and centrifuge at 3100 rpm.

Decant off supernatant again but this time into a suitable (non glass) container for safe disposal later.

Repeat with HCl again, ie. leave 20 minutes, add H₂O, stir, centrifuge, decant.

Repeat with HF again but this time leave overnight in the fume cupboard.

Add H₂O, stir, centrifuge, decant into HF waste container.

HCl again if needed, leave 20 minutes, add H₂O, stir, centrifuge, decant.

Filter residue through a 118 µm mesh into a pyrex jug.

Keep what is left in the jug ie. < 118 µm

Rinse until water is clear (can use glass rod gently stirring on the mesh).

Now sieve through 10 µm mesh ie. open up the sieve and insert the finer mesh (a defloculant can be added at this point to aid sieving).

Keep all the material now retained on the mesh surface.

Use distilled water to rinse this retained fraction into a centrifuge tube (tubes can be quite full but levels must match to retain balance in centrifuge).

Centrifuge as before.

Can wash again if the water is still mucky in the tubes.

ACETOLYSIS

Make up some neutralising solution by scooping some NaH_2CO_3 powder and mix with water in a bowl (1/8 of a jug of powder).

Ensure everything is dry ie. tube caps, rubber gloves, working surfaces etc.

Work in the fume cupboard with main fan switched on.

Take a small 100 ml glass beaker and put in some glacial acetic acid to counteract the H_2O .

Pour into the tubes up to the level of the first shelf in the perspex tube holder.

Place a dry glass stirring rod in each tube.

Pipette a few drops of glacial acetic acid around the inside of each tube (using a pipette with a small rubber bulb).

Give the vials a good stir then place the stirrers in a beaker containing some of the neutralising solution.

Place the black caps on the tubes in the correct order and centrifuge.

Gloves can be dipped in bowl of neutraliser and dried.

After centrifuging decant into a glass jug.

Carefully measure in 9 ml acetic anhydride from the dispenser in the fume cupboard (you have to lift up the top and lower it).

Then carefully 1 ml of sulphuric acid (make sure sulphuric acid comes out and not just air).

Watch for cross contamination if violent reaction occurs causing spill over into another tube.

Stir vials with glass rods and place them in the metal tube holder in the hot-bath for 1 minute.

Then stir again and leave for another minute.

Return tubes to perspex holder and, still using rubber gloves, fill vials up to near top with glacial acetic acid ie. level with top of upper perspex layer on rack.

Stir again (could bring electric mixer into fume cupboard if there is a lot of residue to mix).

Place glass stirrers into glass jug of neutralising solution.

Replace black caps to tubes and centrifuge.

Decant again into glass jug.

Put more glacial acetic acid into the tubes (to wash them again) to top of first level in perspex holder, stir again and centrifuge.

(Put glacial acetic acid away in cupboard below the fume cabinet).

Decant off again into glass jug.

Add distilled and stir (always with a clean glass stirrer) then centrifuge and decant as before.

STAIN

At this point stain can be added.

Using a pipette add one drop if a small amount of pollen is present or two drops if more.

Add distilled on top of first layer, stir and centrifuge.

Wash again ie. distilled, stir and centrifuge.

TBA

Note: TBA is as solid at room temperature so needs to be placed in the hot bath or on the hotplate to keep the bottle warm.

Add 10 ml of TBA to each tube (ie. to the top of the first rack level).

Stir and centrifuge but this time do not decant all the fluid off.

Using a pipette suck the pollen residue off the tube bottom and place into a glass pollen vial (pre-labelled).

Put more TBA on the residue in the centrifuge tube (a few drops) to finish transferring the pollen residue to the pollen vial.

If at this point the glass vial fills up it will have to be centrifuged down to make room and excess TBA poured off (or pipetted off).

Centrifuge the pollen vials using special cradle in the centrifuge and decant off the TBA.

Add silicon oil (2,000 c/s).

Using a cocktail stick let the silicon oil wind around the stick and then drop into the vial putting equal amounts of oil in the vials.

Stir the vials with separate cocktail sticks.

TBA now needs to evaporate either overnight or in the oven for a few hours on 60 degrees.

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PREPARATION OF SLIDES FOR POLLEN COUNTING

1. Carefully check that the slides and coverslips to be used are clean and flat.
2. Place the slide in a jig - fabricated using three slides attached to a smooth piece of wood - which has the outline and centre of the coverslip position marked on it.
3. Place a small drop of silicone oil. (viscosity = 2000 cs) on the slide in the centre position as marked. Stir the vial of prepared sediment with a clean cocktail stick, adding a small amount of silicone oil, if necessary, to achieve a thorough mix. Place a small drop of suspension on the drop of silicone oil on the slide.
4. Mix the oil and the preparation well and spread out into an asterisk shape (*) reaching nearly to the edge of the coverslip area. Remove any large particles with a clean needle and fine forceps.
5. Lower a coverslip vertically onto the spread out sample. (Square coverslips are preferable as they minimise the effects on non-random pollen distribution on the slide).
6. Press gently on the coverslip to expel air bubbles and to coax the suspension to, but not beyond, the edges of the coverslip.
7. Label the slide fully with e.g. indian ink and nail varnish, or small sticky slide label. Allow the slide to stand for 5-10 minutes to equilibrate.
8. The ideal thickness for slides for counting is 15-20 μm , allowing for the maximum utilisation of the resolution of the microscope lenses without causing compression and distortion of the pollen.
9. Check the slide for a suitable concentration of the sediment residue. Ideally there should be little overlap of the particles. There should be no more than about 10 pollen sized particles in a field of view at X400 magnification. If necessary make a new slide adjusting the concentration by adding more or less suspension to more or less silicone oil.
10. Lightly tack the corners of the coverslip with nail varnish.
11. Store the slides flat.

LABORATORY MANUAL AND METHODS
UNIVERSITY OF EXETER
DEPARTMENT OF GEOGRAPHY - PHYSICAL LABORATORIES
(UPDATED MARCH 2005)

POLLEN PREPARATION

Pollen preparations need great care. Cleanliness and good technique are essential for accurate preparations with no contamination. Even more importantly hazardous chemicals are used and so advice must be sought on handling and protective clothing gloves and goggles/facemasks must be worn.

There are many variations on the technique depending on the nature of the sample and so advice must again be sought before the preparation.

AA) Treatment of exotic standard

This only applies to those samples where an absolute value for the pollen is to be estimated.

1. Decide on the number of exotics to be added.
2. Using forceps add these exotic tablets to the 50 ml boiling tube.
3. Add Ca, 30 ml of distilled water and 1 ml of conc. Hydrochloric acid to each boiling tube.
4. After the effervescence has died down, centrifuge the tubes at 2500 rpm for 20 minutes.
5. Decant the supernatant, ensuring no loss of pollens and wash with 40 ml of distilled water.
6. Centrifuge at 2500 rpm for 20 minutes.
7. Repeat stages 5 and 6.

A) Initial Preparation - Wet Samples

1. Decide how much sample to take - usually 0.4 ml.
2. Add a small amount of distilled water to a 5 ml measuring cylinder. To this add sample with a micro-spatula until 0.4 ml (or designated volume) is displaced.
3. Add this mixture to the boiling tube and wash cylinder with the Sodium Hydroxide, adding washings to the boiling tube. Repeat until all the sample has been transferred.
4. Boil the centrifuge tubes in a water bath at 100°C for 20 minutes, stirring regularly.

A) Initial Preparation - Dry Samples

1. Decide how much sample to take - usually 0.2-0.5 g. Weigh the sample into the boiling tube, being careful to not cross contaminate between samples. Note the exact weight (4 decimal places).
2. Add 40 ml 10% Sodium Hydroxide, to the boiling tube.
3. Boil the centrifuge tubes in a water-bath at 100°C for 20 minutes, stirring regularly.

A) Initial Preparation (Calcareous samples)

1. To each boiling tube weigh out 2 gm of sample (weight may vary according to expected pollen).
2. Add a small amount of IMS (to stop frothing) and 1 ml of 10% HCl - wait for effervescence to subside. Repeat until no more effervescence on adding the acid.
3. Centrifuge at 2500 rpm for 10 minutes - discard the excess acid. Wash with distilled water and centrifuge at 2500 rpm for 10 minutes - discard the supernatant.
4. Add 40 ml of 10% Sodium Hydroxide to each boiling tube.
5. Boil the centrifuge tubes in a water-bath at 100°C for 20 minutes, stirring regularly.

Note: Alternatively, the addition of the hydrochloric acid can be performed after the distilled water wash following the first screening (see below), but extra care must be taken with the addition of the acid because of the smaller volume of the test tube.

B) Screening

1. Onto a funnel a 10 μm sieve (nylon cloth) is placed. Above this is a 'cut away' funnel and then a 106 μm brass sieve.
2. Pour the contents of the beaker through this, collecting the liquor as waste in a bottle. Wash the 106 μm sieve with distilled water, collecting the <106 μm fraction on the 10 μm sieve.
3. When the 106 μm sieve has been thoroughly washed, then stir the liquor on the 10 μm sieve and wash this with distilled water until the waste is clear.
4. Wash the residue towards the lip of the sieve, and then using a wash bottle fitted with a jet, wash this entire residue into the 10 ml centrifuge tube.
5. Centrifuge the tubes at 2500 rpm for 10 minutes. Discard the supernatant.
6. Retain the 10 μm sieve as this is used again after the hydrofluoric acid stage.

The macro on the 106 μm sieve is washed into a 100 ml bottle and retained for possible analysis.

The brass sieves are then placed in an ultrasonic bath for thorough cleaning before being soaked overnight in peroxide.

C) Hydrofluoric Acid Digestion

This removes silicas and so may not be necessary for organic samples.

This is a VERY HAZARDOUS substance and so must only be used under supervision and in a fume cupboard with full personal protection (gloves, facemasks, etc).

1. Add about 6-8 ml of the Hydrofluoric acid to the residue in each of the tubes.
2. Stir with a plastic rod. (not glass!)
3. Place in a waterbath at 100°C for 30 minutes.
4. Centrifuge at 2500 rpm for 10 minutes.
5. Discard supernatant into a tub of water.
6. If high amounts of silica anticipated then repeat stages 1-5.
7. Wash residue with distilled water.
8. Sieve through the relevant 10 μm sieve, and wash residue back into the 10 ml centrifuge tube.
9. Centrifuge at 2500 rpm for 10 minutes.
10. Discard supernatant, taking care as, when in water, the pellet is often not very firm.

The waste Hydrofluoric acid from stage 5 is neutralised with Sodium Hydrogen Carbonate in the fume cupboard sink before disposal.

D) Acetolysis

The acetolysis mixture reacts VIOLENTLY with water and so great care must be exercised, again using a fume cupboard and full personal protection.

The Acetolysis Mixture is 9 parts Acetic Anhydride + 1 part conc. Sulphuric Acid.
This should be prepared by a Technician using a fume cupboard.

1. About 2 ml of Glacial Acetic Acid is added to the residue and stirred. The tube is then centrifuged at 2500 rpm for 10 minutes and the supernatant is discarded into a tub of water.
2. Stage 1 is then repeated to ensure that all water is removed.
3. About 6-8 ml of the Acetolysis Mixture is carefully added to the residue.
4. After stirring the tubes are heated at 100°C for 5-10 minutes in a waterbath.
5. The tubes are then centrifuged at 2500 rpm for 10 minutes.
6. The supernatant is then cautiously discarded into a DRY beaker and disposed of by the Technician.
7. If the organic content of the sample is high then repeat stages 3-6.
8. Ca. 2 ml of glacial acetic acid are added to the residue and stirred. The tubes are centrifuged at 2500 rpm for 10 minutes and the supernatant discarded.
9. The residue is now washed with distilled water, centrifuged and then the supernatant discarded.
10. Stage 9 is then repeated.

E) Finishing off (Silicon Oil)

1. To the residue is added ca. 2 ml of 95% alcohol (IMS). After stirring, the tubes are centrifuged at 2500 rpm for 10 minutes. The supernatant is discarded.
2. Stages 1 is now repeated to ensure total removal of water.
3. Ca. 2 ml of 100% alcohol (iso - propanol) is added to the residue. Again this is centrifuged and the supernatant discarded.
4. Ca. 1ml of tertiary butyl alcohol (TBA) is added to the residue. Again this is stirred using the vortex stirrer, centrifuged and the supernatant discarded.
5. 1 ml of tertiary butyl alcohol is again added to the residue and stirred.
6. A small amount of silica oil is added to a labelled vial and the contents of the centrifuge tube are then transferred to this vial using the TBA.
7. The vial is then placed in a heating block at 40°C until the TBA has evaporated (Ca. 2 days).

E) Finishing off (Glycerol)

1. Wash the residue into a labelled vial with distilled water and centrifuged gently at 1500 rpm for 10 minutes.
2. Decant off the water, (the last drop can be dealt with by a piece of tissue, but ensure that there is no loss of solid).
3. Add a few drops of the glycerol and stopper the vial for storage.

An essential part of the preparation is the use of clean equipment. Therefore, after use, all tubes, stirrers, funnels, sieves etc. must be thoroughly washed and then soaked overnight in Hydrogen Peroxide before rinsing with distilled water and stored separately from general laboratory equipment.

Pollen Count Data Sheet V. 1-1 (WDG)	Site:	Level:
Slide:	Analyst:	Date:

Tree Pollen	Herb Pollen	
<i>Betula</i> :	Poaceae [Gramineae] ⁶ :	
<i>Pinus</i> :		
<i>Ulmus</i> :	Cereal ⁶ :	
<i>Quercus</i> :	Cyperaceae:	
<i>Tilia cord.</i> / <i>plat.</i> :	<i>Calluna</i> :	
<i>Alnus</i> :	<i>Empetrum</i> :	
<i>Fagus</i> :	Ericaceae undif.:	
<i>Carpinus</i> :	Asteraceae (Asteroideae/Cardueae) undif. [Compositae (tub.)] ⁷ :	
<i>Fraxinus</i> :		
<i>Acer</i> :	<i>Artemisia</i> type (Asteroideae):	
<i>Populus</i> :	<i>Solidago</i> v. [<i>Aster</i>] type (Asteroideae) ⁸ :	
<i>Abies</i> :	<i>Achillea</i> [<i>Anthemis</i>] type (Asteroideae) ⁸ :	
<i>Picea</i> :	<i>Arctium</i> [<i>Serratula</i>] type (Cardueae) ⁸ :	
<i>Taxus</i> :	<i>Cirsium</i> type (Cardueae):	
	<i>Centaurea</i> (Cardueae):	
	Asteraceae (Lactuceae) undif. [Compositae (Lig.)] ⁹ :	
TOTAL TREE:		
Shrub Pollen	<i>Armeria m.</i> type [A/B]:	
<i>Corylus avellana</i> type (± <i>Myrica</i> []):	<i>Caltha</i> type:	
	Caryophyllaceae:	
<i>Salix</i> :	<i>Campanula</i> type:	
<i>Buxus</i> :	Chenopodiaceae ¹⁰ :	
<i>Juniperus</i> :	Brassicaceae [Cruciferae]:	
<i>Hippophae</i> :	<i>Epilobium</i> type:	
<i>Hedera helix</i> :	<i>Filipendula</i> :	
<i>Ilex</i> :	<i>Helianthemum</i> :	
<i>Ephedra</i> ¹ :	Lamiaceae [Labiatae] ¹¹ :	
	Fabaceae [Leguminosae] ¹² :	
	<i>Oxyria</i> type ¹³ :	
TOTAL SHRUB	<i>Plantago</i> undif.:	
Spore	<i>Plantago lanceolata</i> type ¹⁴ :	
<i>Botrychium</i> :	<i>Polygonum</i> ¹⁵ :	
<i>Equisetum</i> :	<i>Potentilla</i> type:	
<i>Lycopodium</i> ² :	<i>Ranunculus</i> type ¹⁶ :	
<i>Ophioglossum</i> :	Rosaceae undif. ¹⁷ :	
<i>Osmunda</i> :	Rubiaceae undif. ¹⁸ :	
<i>Polypodium</i> :	<i>Rumex acetosa</i> type:	
<i>Selaginella</i> :	<i>Rumex</i> ¹⁹ :	
<i>Pteridium aquilinum</i> :	Saxifragaceae undif. ²⁰ :	
<i>Pteropsida</i> [<i>Filicales</i>] (monolete) undif. ³ :	<i>Succisa</i> :	
	<i>Thalictrum</i> :	
<i>Pteropsida</i> (trilete) undif. ⁴ :	<i>Urtica</i> ²¹ :	
	Apiaceae [Umbelliferae] undif. ²² :	
	<i>Valeriana</i> :	
TOTAL SPORE:		
Obligate aquatic spores ⁵		
<i>Sphagnum</i> :		
<i>Isoetes</i> :	TOTAL HERB:	

Aquatic Pollen	Potamogeton ²⁴ :	Indeterminate
<i>Alisma</i> type:	<i>Sparganium erectum</i> :	Broken:
<i>Hydrocotyle vulgaris</i> :	<i>Typha angustifolia</i> type:	Concealed:
<i>Menyanthes trifoliata</i> :	<i>Typha latifolia</i> type:	Corroded:
<i>Myriophyllum</i> ²³ :		Crumpled:
<i>Nuphar</i> :		Degraded:
<i>Nymphaea alba</i> type:	TOTAL AQUATIC:	TOTAL INDETERMINATE:

Pre-Quaternary microfossils:	Dinoflagellate cysts:
Exotic:	TOTAL DRY LAND / MAIN SUM:

24/06/13

C:\LABTECH\POLLEN\POLCOUNT.DOC

NOTE:

- 1 *Ephedra* can be further sub-divided into *Ephedra distachya* and *E. fragilis*.
- 2 *Lycopodium* is often added as an exotic marker, however differentiation between added and fossil pollen should be possible. This trilete spore may be subdivided *Lycopodium annotinum* type, *Lycopodium clavatum*. Degraded grains may key out as *Pteropsida* (trilete) undif.³.
- 3 This category could include any of the above spores due to the loss of outer coat making differentiation impossible. Polypodeace. Other monocolpate spores that can be determined include *Thelypteris palustris*, *Dryopteris dilatata*, *Dryopteris filix-mas*, and *Dryopteris cristata* type, MWC 1991.
- 4 Other trilete spores may key out as *Adiantum capillus-veneris*, *Anogramma leptophylla*, *Anthoceros punctatus* type, *Botrychium lunaria* type, *Cryptogramma crista*, *Diaphasiastrum* type, *Huperzia, selago*, *Hymenophyllum*, *Lycopodiella inundata*, *Lycopodium annotinum* type, *Lycopodium clavatum*¹ *Ophiglossum vulgatum* type A/B, *Osmunda regalis*, *Phaeoceros laevis*, *Pilularia globulifera* microspores, *Pilularia* microspores, *Riccia* type, *Selaginella selaginoides*, and *Trichomanes speciosum*, MWC 1991.
- 5 These species are dependant upon waterlogged conditions and can occur in such abundance that they swamp samples and therefore must be calculated outside the main sum.
- 6 Grasses are defined as below; Poaceae (wild grass group) = Mean annulus diameter < 8µm, mean grain size < 37µm, surface scabrate or verrucate; Cereal undif. can be further sub-divided into *Hordeum* group = Mean annulus diameter 8-10µm, mean grain size 32-45µm, surface scabrate; *Glyceria* = water grass easily mistaken for the *Hordeum* group; *Avena-Triticum* group = Mean annulus diameter > 10µm, mean pollen grain size > 40µm, surface verrucate; and *Secale cereale* = Mean annulus diameter 8-10µm oblong grain outline (high pollen index), surface scabrate, MWC 1991.
- 7 Asteraceae can be divided into Asteroidea and the Lactucoeidae. The Lactucoeidae can be further sub-divided into the Cardueae and Lactucae. The old division of the Compositae based upon pollen morphology known as the Compositae Liguliflorae can now be referred to as Asteraceae (Lactucae) undif. however the Compositae Tubuliflorae covers a wider taxonomic grouping and is now referred to as Asteraceae (Asteroidea/Cardueae) undif. BWE 1994.
- 8 Divisions as suggested by BWE 1994.
- 9 Asteraceae (Lactucae) undif. are part of the Asteraceae Lactucoeidae, S 1991
- 10 Includes Amaranthaceae, MWC 1991.
- 11 Lamiaceae includes species which key to *Marrubium vulgare*, *Mentha* type, *Prunella* type, *Stachys sylvatica* type, *Stutellaria* type and *Teucrium*, MWC 1991.
- 12 Fabaceae includes species which key to *Astragalus danicus* type, *Coronilla varia*, *Galega officinalis* type, *Hippocrepis comosa*, *Lotus* type, *Medicago sativa*, *Onobrychis* type, *Ononis* type, *Ornithopus perpusillus*, *Robinia pseudoacacia*, *Trifolium* type, *Trifolium spadiceum*, *Ulex* type, *Vicia* type and *Vicia cracca* type, MWC 1991.
- 13 *Oxyria* type includes *Oxyria digyna*, *Rumex crispus*, *R. conglomeratus*, *R. sanguineus*, *R. pulcher*, *R. maritimus*. *Oxyria* and *R. acetosella* are <26µm, *Oxyria* also has a more clearly circular porus which is ringed in phase contrast, MWC 1991.
- 14 Varieties of *Plantago* can be keyed out to *P. maritima* type, *P. major*, *P. media*, and *P. coronopus*, MWC 1991..
- 15 Varieties of *Polygonum* can be keyed out to *P. amphibium*, *P. aviculare* type, *P. bistorta* type, and *P. persicaria* type.
- 16 Within *Ranunculus* type it may be possible to identify *Eranthis hyemalis* and *Pulsatilla vulgaris* MWC 1991
- 17 Rosaceae undif. can be sub-divided into *Sanguisorba minor* ssp. *minor*, *Agrimonia eupatoria*, *Crataegus*, *Dryas octopetala*, *Malus sylvestris*, *Mespilus germanica*, *Potentilla* -type, *Prunus*, *Pyrus pyrausta*, *Rosa*, *Rubus*, *Sorbus*, MWC 1991.
- 18 *Galium* type is the only definable member of the Rubiaceae and includes *Galium*, *Asperula*, *Rubia* and *Sherardia*, MWC 1991.
- 19 Certain varieties of *Rumex* also key out to *Oxyria* type or *Rumex obtusifolius* type, MWC 1991.
- 20 Saxifragaceae undif. includes *Saxifraga androsacea*, *S. cernua* type, *S. granulata* -type, *S. hirsuta* type, *S. oppositifolia* type and *S. stellaris* type, MWC 1991
- 21 *Urtica* can be sub-divided into *Urtica dioica*, *U. pilulifera* and *U. urens*, MWC 1991.
- 22 Apiaceae undif. can be further sub-divided into groups with similar morphological characteristics, MWC 1991
- 23 *Myriophyllum* can be sub-divided in to *M. alterniflorum*, *M. spicatum* and *M. verticillatum*, MWC 1991.
- 24 *Potamogeton* can be divided in to two subgenera *Potamogeton* subgenus *Potamogeton* type and *Potamogeton* subgenus *Coleogeton*, MWC 1991.

References

- BWE 1994 Bennet, K.D., Whittington, G. & Edwards, K.J. 1994 Recent plant nomenclatural changes and pollen morphology in the British Isles *Quaternary Newsletter* 73:1-6
- MWC 1991 Moore, P.D., Webb, J.A. & Collinson, M.E. 1991 *Pollen Analysis* (2nd ed.) Blackwell Oxford
- S 1991 Stace, C. 1991 *New Flora of the British Isles* Cambridge University Press Cambridge

DEPARTMENT OF GEOGRAPHY

POLLEN PREPARATION

	SITE								DATE			
Ref. nos.												
Tube nos.												
Hot HCl												
Wash H ₂ O												
Hot NaOH												
Sieve												
Wash H ₂ O												
Wash HCl												
HIF cold/hot												
Hot HCl												
Wash H ₂ O												
Wash CH ₃ COOH												
Acetolysis												
Wash CH ₃ COOH												
Wash H ₂ O												
Wash 1% NaOH												
Wash H ₂ O												
Wash H ₂ O + Safranin												
Wash TBA												
Vial of remainder												

REMARKS

Date.....

[illegible]

KEY: - = none
O = occasional
F = frequent
A = abundant

Date.....

KEY: - = none
 + = occasional [Small <50k, Large <20k]
 ++ = frequent [Small <50-300k, Large 20-100k]
 +++ = abundant [Small >300k, Large >100k]

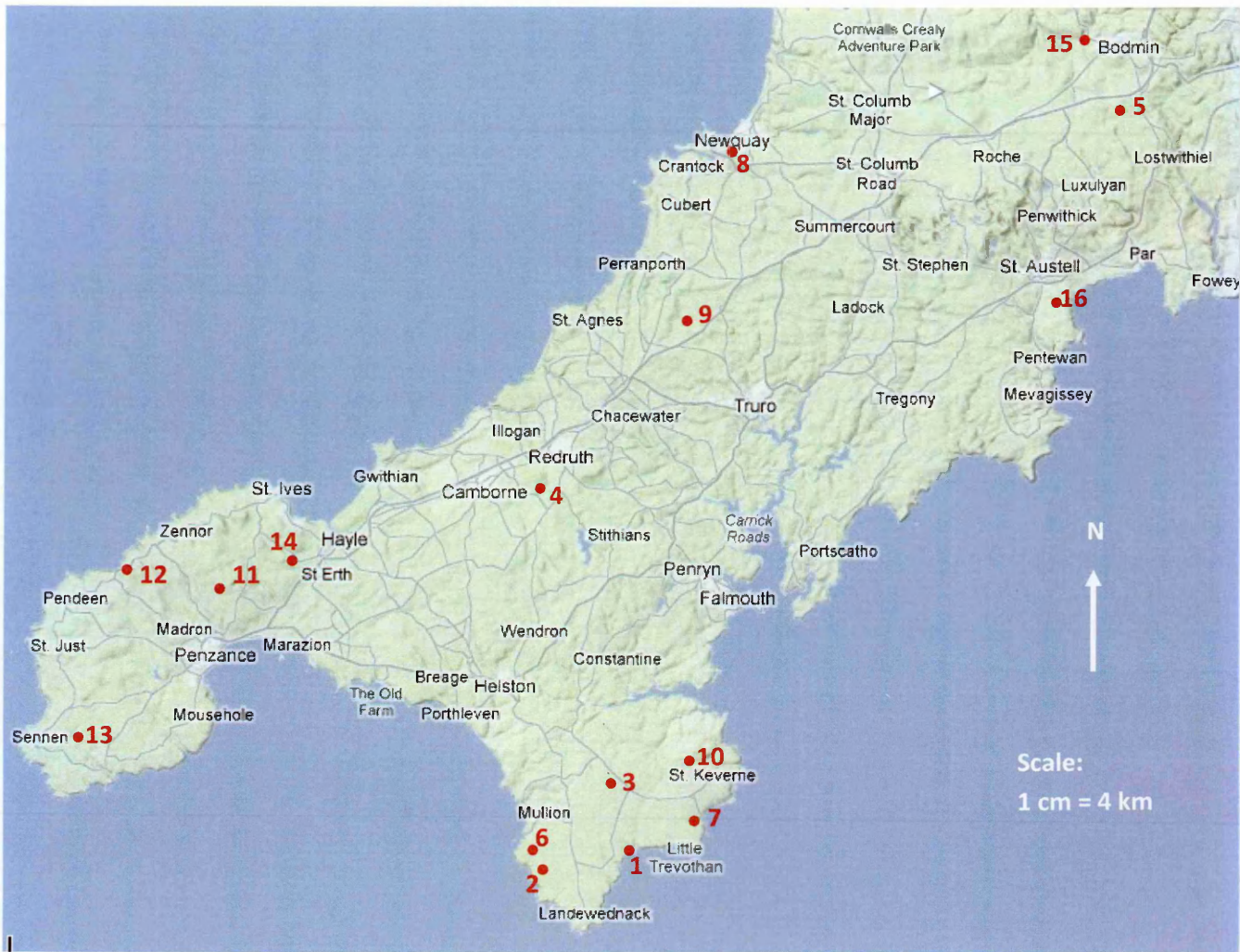
 \sim = number of scans in count

Appendix II

Lizard Peninsula location maps showing:

- Location of archaeological sites mentioned in Section 1.5 i
- Location of Holocene sites ii
 - sites investigated for this thesis
 - sites visited but not included in this study
 - sites previously investigated

Appendix II



Location of western Cornwall archaeological sites mentioned in Chapter I

Mesolithic

- 1. Poldowrian
- 2. Windmill Farm
- 3. Croft Pascoe

Neolithic

- 4. Carn Brea
- 5. Helman Tor

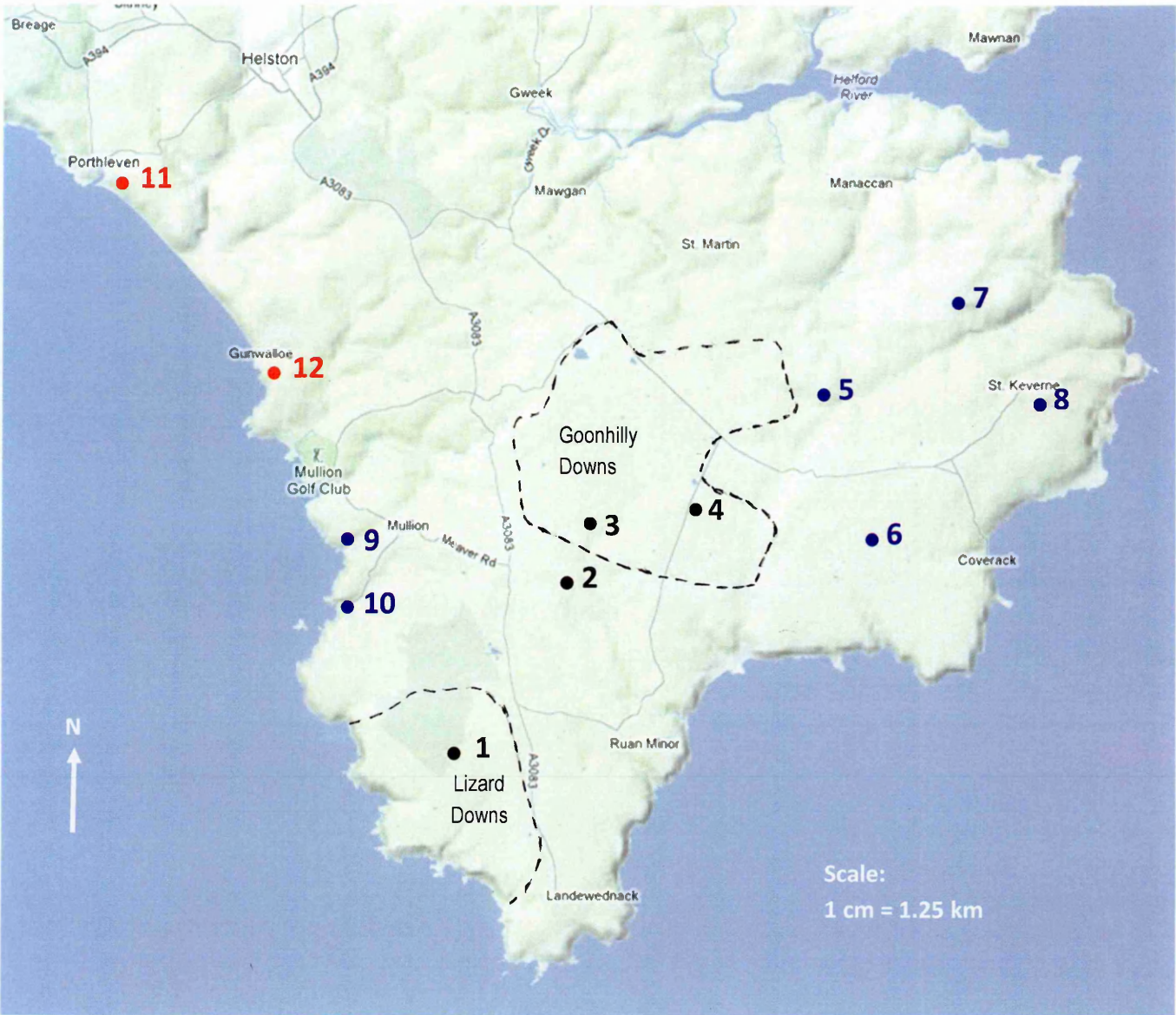
Bronze Age

- 1. Poldurian
- 6. Kynance Gate
- 7. Polcoverack
- 3. Goonhilly (Croft Pascoe)
- 8. Trethallon
- 9. Callestick

Iron Age and Romano-British

- 6. Kynance Gate
- 10. St. Keverne (Trebarveth)
- 11. Chysauster
- 12. Porthmeor
- 13. Carn Euny
- 14. Trencrom
- 15. Nanstallon (Roman)
- 16. Castle Gotha

Appendix II



Sites investigated for this thesis

- 1. Lizard Downs site (Section 2.1)
- 2. Hendra site (Section 2.4)
- 3. Erisey Barton site (Section 2.2)
- 4. Croft Pascoe site (Section 2.3)

Sites previously investigated

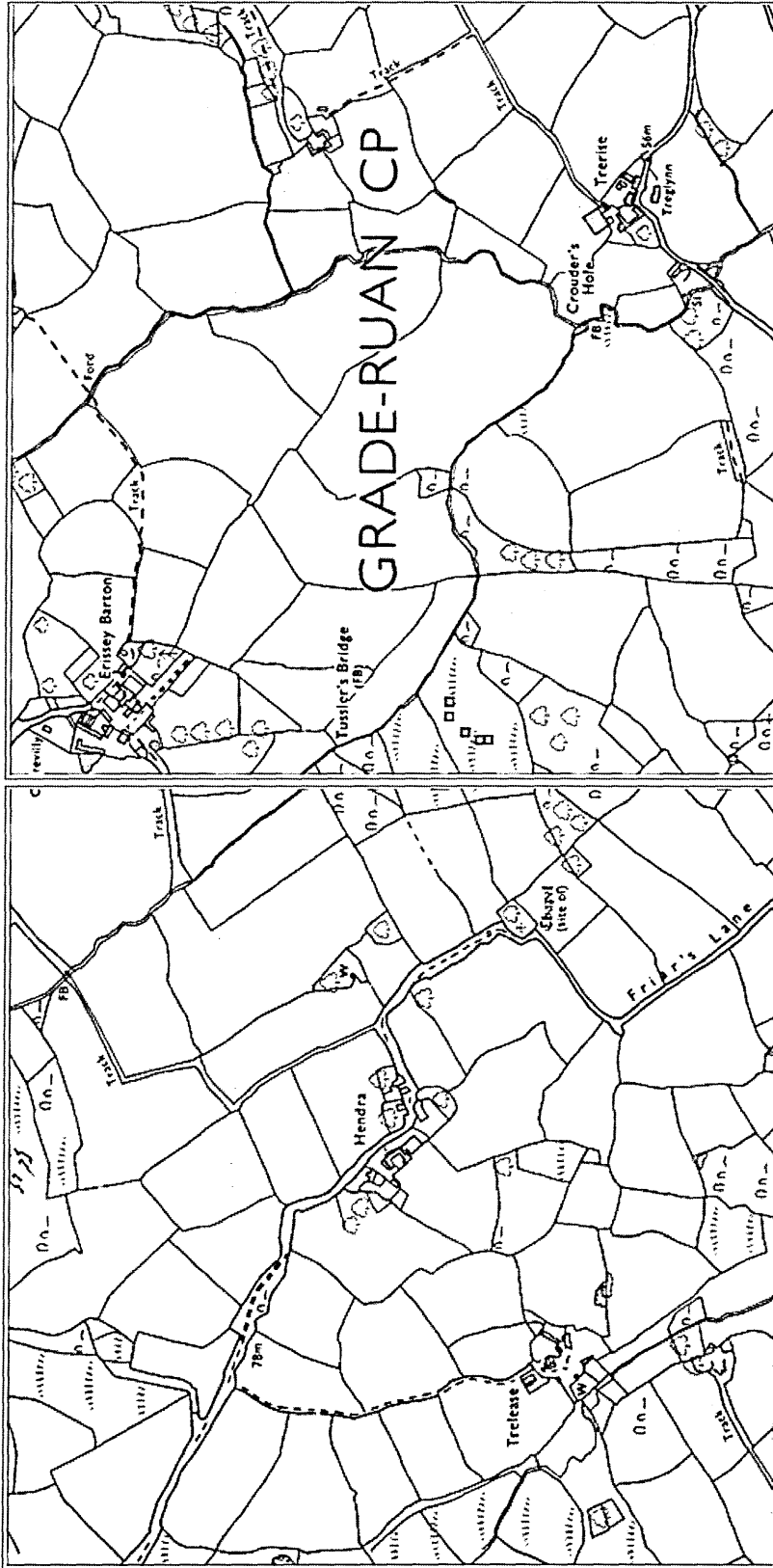
- 11. Porthleven Harbour (Environment Agency Report, 1999)
- 12. Church Cove, Gunwalloe (French, 1996)

Sites visited but not included in this study

- 5. Trelease (access denied by landowner)
- 6. Crousa Downs (poor sediment)
- 7. Tregarne (too far from heathland)
- 8. Roskilly (minimal heathland signal in pilot samples)
- 9 & 10 Polurrian and Mullion Coves (no deposits found)

Appendix III

Juncus subnodulosus location map



Appendix III

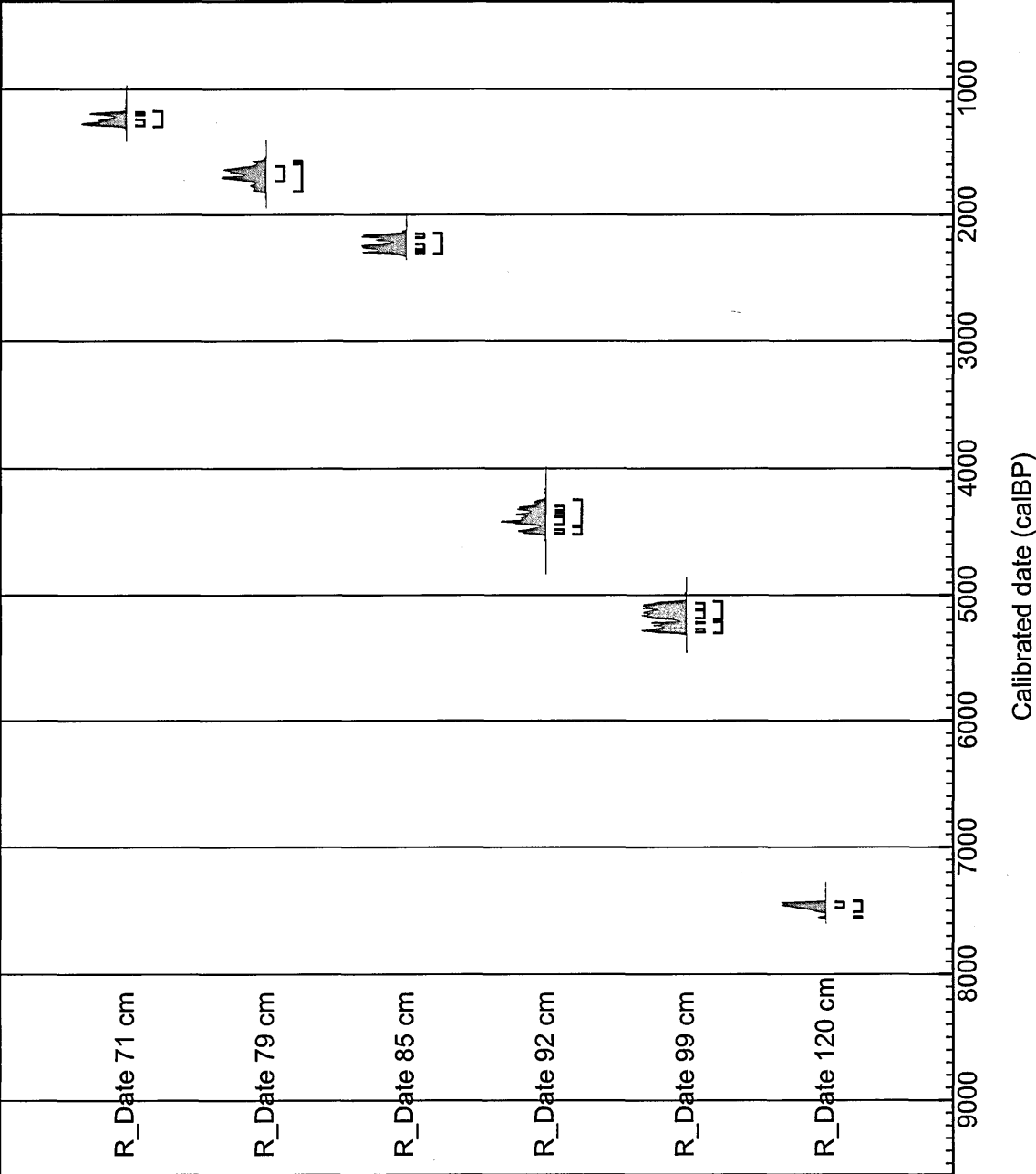
Location of *Juncus subnodulosus* (red squares) at the Hendra mire site (courtesy of Ian Bennallick, BSBI, 2010).

Appendix IV

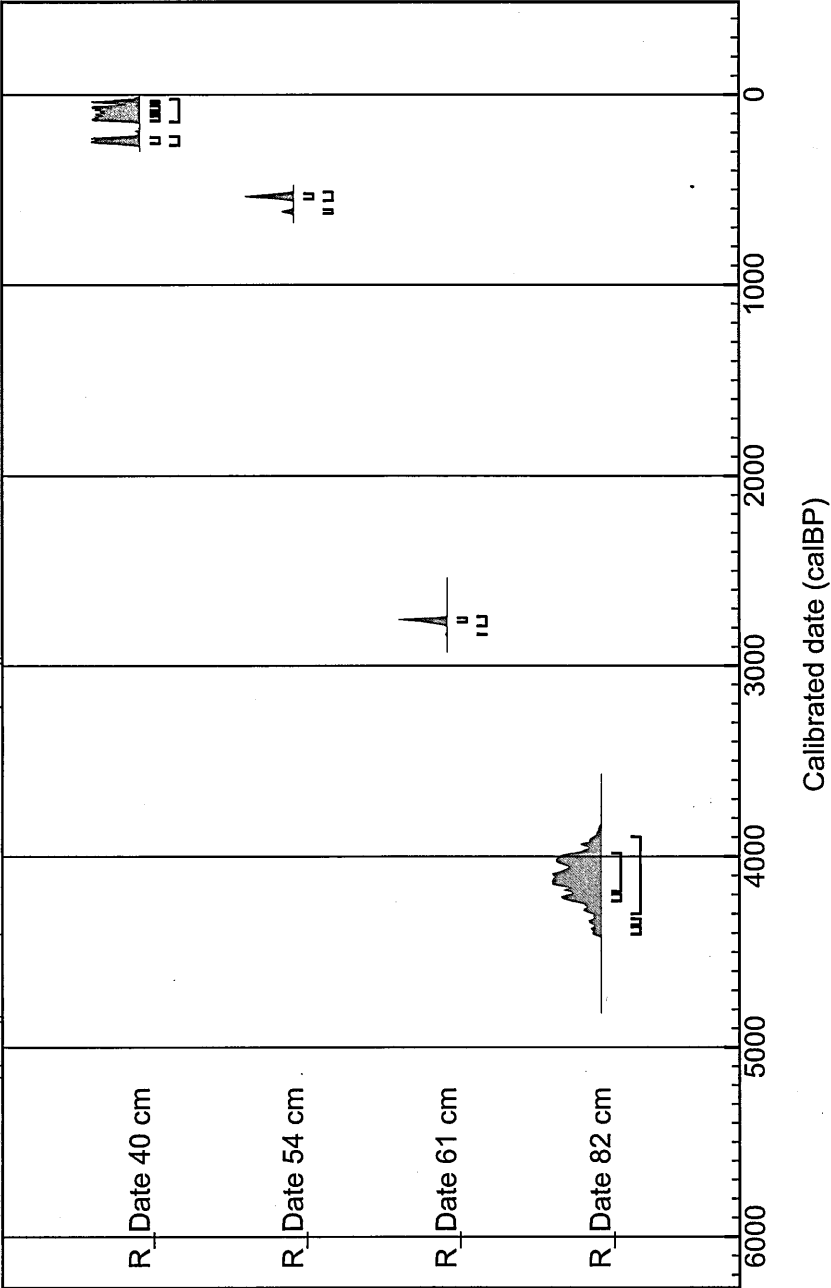
Oxcal. ^{14}C calibration graphs:

- Hendra HENI
- Croft Pascoe CPAI
- Erisey Barton EBA2

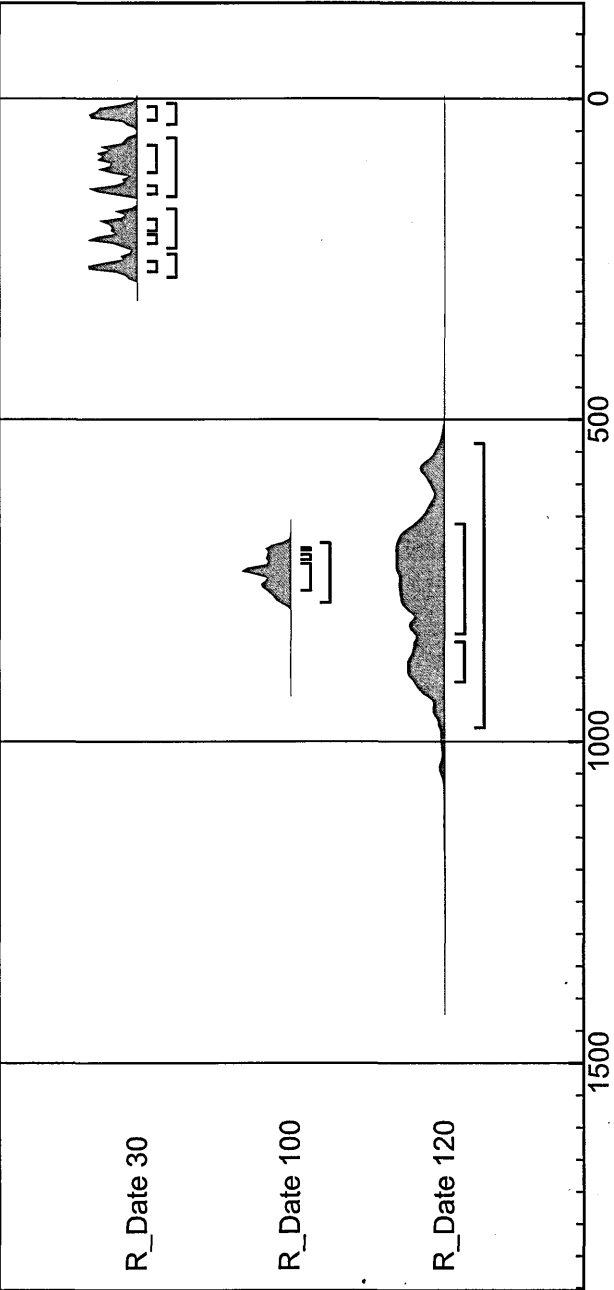
OxCal v4.1.7 Bronk Ramsey (2010); r:5 Atmospheric data from Reimer et al (2009);



OxCal v4.1.7 Bronk Ramsey (2010). r.5 Atmospheric data from Reimer et al (2009).



OxCal v4.1.7 Bronk Ramsey (2010); r5 Atmospheric data from Reimer et al (2009);



Calibrated date (calBP)

Appendix V

- Sediment Key i

Adapted from Troels-Smith (1955)

- Pollen Diagram Colour Key ii

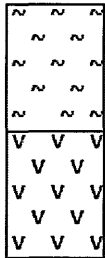
Appendix V

1. Representations of sediment types used in the pollen diagrams. Adapted from Troels-Smith (1955).



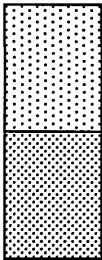
Th* Turfa herbacea

Top: density 2
Bottom: density 3



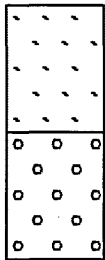
Top: Sh* Substantia humosa

Bottom: Th (Phra.)* Turfa herabcea (Phragmites)



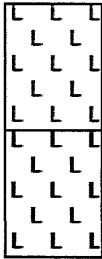
Top: Gs Grana suburralia (2 – 0.6 mm)

Bottom: Ga Grana arenosa (0.6 – 0.06 mm)



Top: Dh* Detritus herbosus

Bottom: Gg (min.) Grana glareosa (> 2 mm)



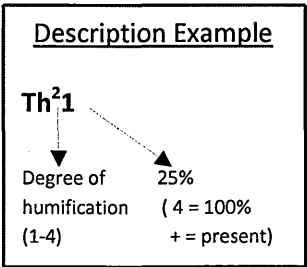
Top: Ag Agrilla granosa (0.06 – 0.002 mm)

Bottom: As Agrilla steatodes (<0.002 mm)

Sediment Description abbreviations (from Birks and Birks, 1980 pp.42-43)

- Th* Turfa herbacea Roots, intertwined rootlets, rhizomes, of herbaceous plants ± stems, leaves connected with these
- Sh Substantia humosa Completely disintegrated organic substances and precipitated humic acids
- Dh* Detritus herbosus Fragments of herbaceous plants >2 mm
- Gs G. suburralia Coarse sand
- Ga Grana arenosa Fine sand
- Gg G. glareosa Gravel
- Ag A. granosa Silt
- As Agrilla steatodes Clay

* sediment elements that can be humified




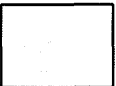


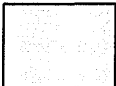




Appendix V

Physical Properties abbreviations

- nig - nigor, degree of darkness – nig 0 lightest, nig 4 darkest
- strf - stratification, degree of stratification – strf 0 homogenous, strf 4 many layered
- elas - elasticas, degree of elasticity – elas 0 no elasticity, elas 4 highest degree of elasticity
- sicc - siccitas, degree of dryness – sicc 0 pure water, sicc 4 air dry
- humo - humositas, degree of humification – 1 slightly humified, 4 very humified

2. Colour coding used in pollen diagrams

	Trees x 1		Trees x 0.3
	Shrubs		
	Herbs x 1		Herbs x 0.3
	Ericaceae		
	Spores x 1		Spores x 0.3
	Aquatics		

Appendix VI

Pollen Main Sums

Appendix VI - Pollen Main Sums

Total dry land pollen (TLP) was counted up to the target main sum unless the material ran out or the counting was abandoned due to the very slow pace of data collection. This may have resulted from very low pollen density (i.e. very high exotic count) or excessive cellulosic debris and/or very poor pollen preservation. In some cases a slide was prepared but counting was not attempted due to the low density and poor preservation of the pollen and the resulting insecurity of pollen identification. Spores were not included in the main sum. The *Lycopodium* spore batch* is also indicated in the tables (see explanation below).

I. Erisey Barton

The target TLP main sum less Cyperaceae was 300.

depth/cm	TLP - Cyperaceae	<i>Lycopodium</i> batch*	notes
0	298	C	
5	309	C	
10	225	C	material finished
15	293	C	
20	326	C	
25	302	C	
30	341	C	
35	336	C	
40	304	C	
45	245	C	material finished
50	333	C	2 samples prepared, 45 + 288
55	343	C	
60	303	C	
65	329	C	
70	355	C	
75	352	C	
80	334	C	
85	326	C	
90	335	C	
95	316	C	
100	326	C	
105	-	C	counting not attempted
110	312	C	
115	63	C	counting abandoned
120	298	C	

2. Croft Pascoe

The target TLP main sum was 400.

surface samples	TLP	<i>Lycopodium</i> batch*	notes
1	464	C	
2	389	C	
depth/cm	TLP		notes
39	514	C	
40	-		counting not attempted
45	455	C	
48	459	C	
52	454	C	
55	476	C	
57	436	B	
59	411	B	
60	438	C	
61	432	B	
62	426	C	
65	423	C	
67	411	B	
70	390	C	
72	-		counting not attempted
73	408	B	
75	385	C	
77	460	C	
80	417	C	
82	419	B	
85	447	C	

3. Hendra – HENI

The target TLP main sum was 400.

surface samples	TLP	<i>Lycopodium</i> batch*	notes
1	599	C	
2	762	C	
depth/cm	TLP		notes
10	462	C	
15	-		counting not attempted
20	654	C	
25	448	C	
32	433	C	
37	408	C	
40	392	C	
45	-		counting not attempted
46	276	C	counting abandoned
50	360	C	
55	202	C	material finished
60	425	C	
65	414	C	
70	223	C ²	counting abandoned
72	404	B	
75	415	C	
78	397	B	
80	373	C	
81	442	B	
82	400	B	
83	308	B	counting abandoned
84	425	B	
85	238	C	counting abandoned
86	132	B	material finished
88	347	B	counting abandoned
90	206	C ²	counting abandoned
92	-		
95	427	C	
100	258	C ²	counting abandoned
105	392	B	
110	231	C ²	counting abandoned
115	436	C	
120	273	C ²	counting abandoned

4. Hendra – HEN2

The target total tree pollen (TTP) sum was 100.

depth/cm	TLP	TTP	<i>Lycopodium</i> batch*	notes
95	212	144	C	material finished
97	-	-		counting not attempted
98	-	-		“
99	-	-		“
100	125	62	C	material finished
103	517	104	B	
105	618	112	B	
108	219	90	C	counting abandoned
111	626	94	B	
113	434	95	C	
114	721	111	C	
115	500	137	C	
116	429	110	C	
117	421	166	C	
120	406	195	C	

* *Lycopodium* spore tablet batches:

- C Batch no. 938934 X = 10,679 (Cornwall College supplied)
- B Batch no. 483216 X = 18,583 (Bangor supplied)

One tablet was added to each sample but for five HEN1 samples to which two tablets were added due to the relatively higher volume of sediment used. These are indicated above as C².

Appendix VII

Croft Pascoe transect data

Appendix VII

Raw sediment depth data from the Croft Pascoe linear feature. The depth of the sediment along twelve transects 25 m apart was measured (35 m between transect 11 and 12). The base of the feature was taken as the distance from the surface when no further penetration of the auger could be achieved.

* indicates the measurement at the approximate centre of the wet area.

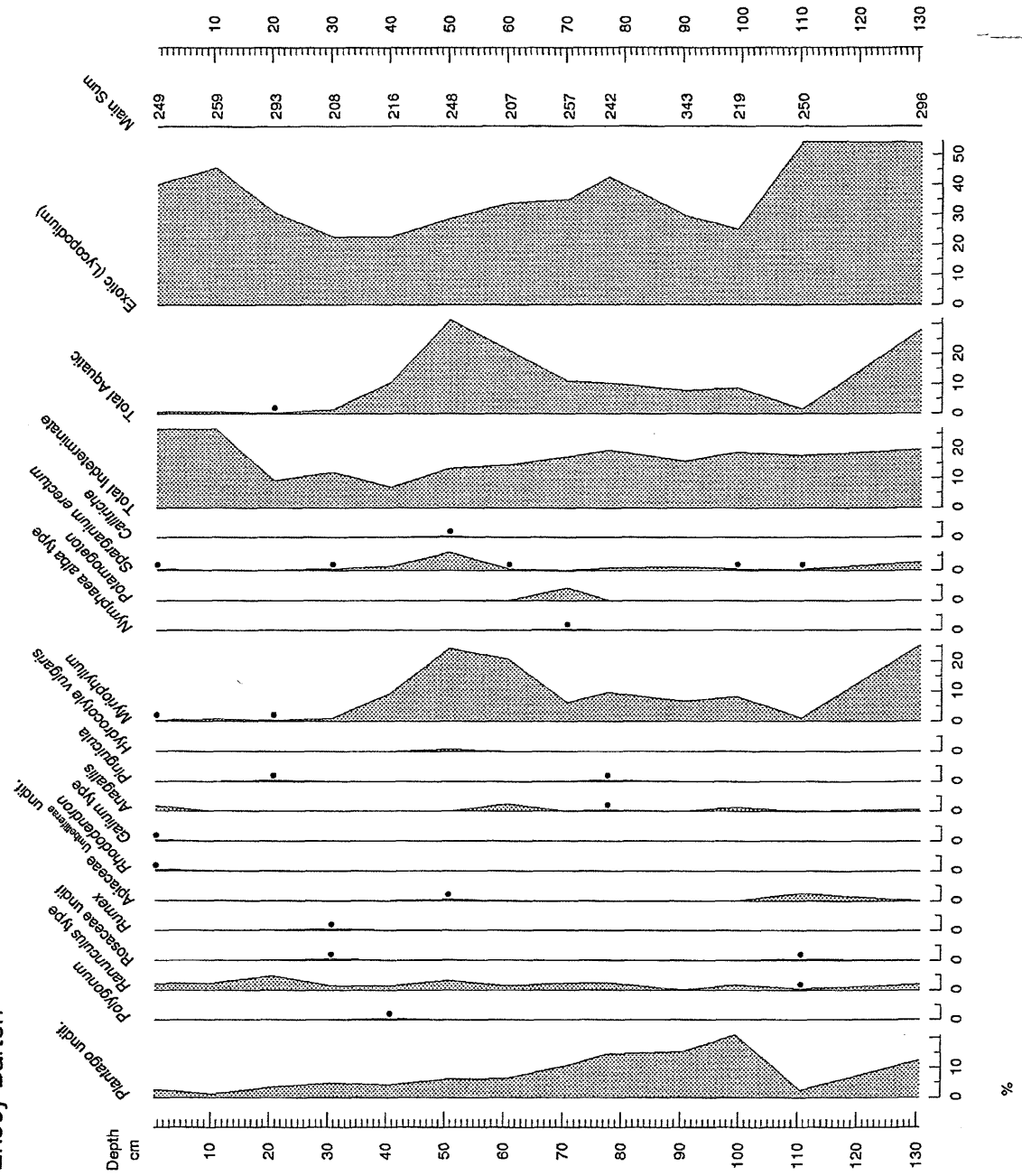
 Approximate width of the wet area (August 2011)

Transect number	Depth of sediment/cm at 2 m intervals											
	1	2	3	4	5	6	7	8	9	10	11	12
1	20	20	20	21	8	8*	14	15	13	19	20	19
2			29	25	20	20*	12	20	13			
3		24	17	15	19	25*	20	17				
4			17	14	16	18*	23	27	27			
5		20	19	20	24	56*	61	41	25			
6			24	23	40	53*	61	67	20			
7				11	54	23*	11	22	14			
8				10	18	17*	14	30	18			
9				12	45	19*	31	21				
10		16	32	29	24	23*	65	67	19	57	13	
11				12	14	20*	20	13				
12				13	10	10*	20	13				

Appendix VIII

Erisey Barton pilot diagrams

Erisey Barton



Appendix IX

Key to soil descriptors pp. i - vi

(From Staines, 1984. pp. 42-50)

Appendix IX

Key to soil descriptors

(From Staines, 1984. pp. 42-50)

Soil horizons

Horizons result from a combination of weathering processes which include:

1. Addition and accumulation of plant residues;
2. Faunal activity;
3. Solution, hydration, oxidation, hydrolysis and physical comminution;
4. Leaching, podzolization and mechanical eluviation, involving downward movement in percolating water of dissolved or suspended solids;
5. Gleying: the mobilization and redistribution or removal of compounds, particularly of iron, under anaerobic conditions associated with periodic waterlogging;
6. Aggregation of fine earth into soil structures replacing geological structure.

These processes are influenced by local factors, principally parent material type and the environment, including modifications by man.

Soil horizons are conventionally distinguished by a letter notation which is more fully explained in Hodgson (1976). Only horizons present in this district are described.

Horizon notation

- O Peaty horizon accumulated under wet conditions.
 - Oh Amorphous peaty horizon.
- A Mixed mineral-organic horizon at or near the surface.
 - Ah Uncultivated A horizon darker than horizon below that has at least 1 per cent organic matter (0.6 per cent organic carbon).
 - Ap Surface horizon evidently mixed by cultivation.
 - Ahg A horizon with dominant moist chroma of 2 or less and common
 - Apg or many ferruginous mottles caused by periodic saturation with water.
- AB Horizon transitional between A and B horizons.
- E Subsurface mineral horizon that is lighter in colour and contains less organic matter and/or dithionite-extractable iron and/or silicate clay than the horizon below, usually due to the removal of one or more constituents.
 - Eb Brownish E horizon usually overlying Bt horizon containing significantly more clay.
 - Eg E horizon with a greyish colour and ferruginous or ferri-manganiferous mottles attributable to reduction and segregation of iron caused by periodic saturation with water in the presence of organic matter.
- B Mineral subsurface horizon without rock structure and differentiated from horizons above and below by colour, soil structure or illuvial concentrations or a combination of these.
 - Bg B horizon that has common or many ferruginous mottles, accompanied by grey or grayish ped faces, matrix colours or many grey mottles within peds. In the absence of ferruginous mottles ped faces must be grey.

Appendix IX

- Bt B horizon containing translocated silicate clay. It contains significantly more clay than horizons above and below, and if peds are present it shows clay coats on ped surfaces or in fine pores and/or concentrations of strongly oriented clay covering at least 2 per cent of a representative thin section.
- Btg Gleyed Bt horizon.
- Bt(g) Bt horizon with gleying too slight to qualify as Btg.
- Bw B horizon that has evidence of weathering and/or structural reorganization and does not qualify as Bt or Bg.
- Bw(g) Bw horizon with gleying phenomena too slight to qualify as Bg.
- Bs B horizon enriched with sesquioxides in which the total of pyrophosphate extractable Fe and Al is at least 0.3 and amounts to more than 5 per cent of the conventionally measured clay content. These horizons commonly have a pelley type of microfabric.
- BC Horizon transitional between B and C horizon, it may qualify for a g or t suffix.
- C Unconsolidated or weakly consolidated mineral horizon that retains rock structure and lacks properties of A, E and B horizons.
- Cu Unconsolidated C horizon lacking evidence of gleying, accumulation of carbonates or soluble salts, or fragipan properties.
- Cr Weakly consolidated little altered substratum that prevents root penetration except along cracks with an average horizontal spacing of at least 10 cm.
- Cg Gleyed C horizons, characterized by grey colours.
- CG Strongly gleyed C horizon characterized by bluish or greenish colours that change on exposure to air, indicating presence of readily oxidizable ferrous compounds.
- R Hard rock lacking cracks that are penetrable by roots.

Horizons with the same letter notation in a vertical sequence are denoted by numeral suffixes, e.g. Bw1; Bw2. Lithological discontinuities are designated by a numerical prefix, the prefix 1 being understood; the succeeding ones are numbered 2, 3, etc.

Soil classification

Soil classes are distinguished by reference to the particle-size and mineralogical composition of the soil material, the presence or absence of particular diagnostic horizons or other defined differentiating characteristics (see below).

Particle-size classes are grouped (Appendix I) to provide a basis for describing soil lithology. Where horizons of contrasting particle size occur in sequence, group names may be used in combination, e.g. fine loamy over clayey.

Organic soil materials have more than 12-18 per cent organic carbon, depending upon clay content, and humose materials have more than 4.5-7 per cent (Appendix I).

The term Serpentinic is introduced here to differentiate soils in which the amount of exchangeable magnesium is large and exceeds exchangeable calcium by a factor of 2 or more.

Diagnostic horizons in Lizard soils

Surface horizons

Peaty topsoil

O horizons 7.5-40 cm thick; if uncultivated is thick enough to give an Op horizon if mixed to 15 cm.

Humose topsoil

Dark A or sequence of H or Oh and Ah horizons that is humose or partly humose and partly organic (<7.5 cm) over more than 15 cm.

Thick man-made A horizon

A dark A horizon at least 40 cm thick resulting from earthy or organic additions, or deep cultivation of soils rich in organic matter (>0.6 per cent organic carbon throughout).

Distinct topsoil

A surface horizon that is at least 5 cm thick and has at least 0.6 per cent organic carbon if mixed to 15 cm.

Earthy topsoil

A fully ripened peaty surface layer with granular or blocky structure.

Subsurface horizons

Podzolic B horizon A Bh, Bs, Bf or combination of these horizons >10 cm thick extending below 30 cm (>2.5 cm if Bh only).

Argillic B horizon A Bt horizon >5 cm thick which extends below 30 cm or starts within 1.2 m.

Paleo-argillic B An argillic B horizon that also has a dominantly strong brown to red colour, or red mottles, attributable to soil formation in the Ipswichian interglacial period or earlier.

Weathered B horizon A Bw horizon at least >5 cm thick extending below 30 cm.

Gleyed subsurface horizon An Eg, Bg, Btg, Cg or CG horizon >5 cm thick extending below 30 cm.

Gleyic features Eg, Bg, Btg, BCg or Cg horizon within 40-80 cm depth or specified weaker expressions of gleying starting within 60 cm (ochreous mottles, paler ped faces or matrix colours).

Slowly permeable subsurface A subsurface horizon at least 15 cm thick with a saturated hydraulic conductivity of <10 cm/day usually with a measured air capacity (Ca) of <5%. This is the result of massive, platy or normally coarse weakly developed structure, low porosity and high packing density.

Sandy soil Soil in which at least half of the upper 80 cm of mineral soil is sandy, sandy-skeletal or sandy-gravelly.

Pelo-features A clayey layer more than 30 cm thick starting within 30 cm with no more than 15 cm of overlying material with less than 30 per cent clay; a gleyed subsurface horizon, slowly permeable subsurface horizon, gleyic features or some combination of these is required but no paleo-argillic B horizon.

Soil classes present in this district are described more comprehensively below following the Soil Classification devised by Avery (1980).

Major group—Lithomorphic soils

These soils have a distinct, humose or peaty topsoil; a little altered mineral substratum (normally C or R) starting at or within 40 cm depth; no diagnostic weathered, argillic or podzolic B horizon; no gleyed subsurface horizon unless it is extremely calcareous; and no disturbed subsurface layer.

Group—Rankers. These are non-calcareous lithomorphic soils, usually having bedrock or skeletal material within 40 cm depth. Brown rankers have distinct topsoils with no evidence of gleying and are normally brown coloured but can have thin (<15 cm thick) humose topsoils. Stagnogleyic rankers have distinct topsoils and show gleyic features attributable to periodic waterlogging. In this district these soils are less than 30 cm thick over rock; seasonal wetness on the gentle slopes is caused by an impermeable subsurface horizon on the rock.

Group—Sand pararendzinas. These are lithomorphic soils in calcareous sandy deposits other than recent alluvium, chiefly dune sands. Typical sand pararendzinas lack gleyic features and have a distinct topsoil over a sandy Cu horizon that extends below 30 cm depth.

Major group—Brown soils

These soils have a weathered or argillic B horizon, normally brownish or reddish, and no gleyed subsurface horizon.

Group—Brown earths. This soil group, the most widespread in the district, has a weathered B horizon of uniform brown colour above 40 cm but may include gleying below. Typical brown earths lack gley features above 80 cm and comprise loamy, friable and well-aerated profiles with no impedence to drainage. Stagnogleyic brown earths have gleyic features due to intermittent waterlogging. In this district those soils have a slowly permeable, coarsely structured loamy or clay subsoil. The gleyic brown earths subgroup is similarly gleyed but soils are relatively pervious and waterlogging can be associated with a groundwater-table. Profiles of both gleyic and stagnogleyic subgroups can show large variations in the degree of mottling.

Group—Argillic brown earths. These are brown soils that have argillic (Bt) horizons containing argillans and significantly more clay than overlying horizons. Stagnogleyic brown earths have gleyic features, a slowly permeable subsurface and a Bt horizon. Intermittent waterlogging is due, in part, to a slowly permeable subsoil.

Group—Paleo-argillic brown earths. These are brown soils with a paleo-argillic B horizon. They are mainly developed in Wolstonian or older drift and are associated with pre-Devensian ground surfaces which have survived as elements of the present landscape with only superficial modification. In this district these soils are developed in layered materials, the lower of which may be the older. Stagnogleyic paleo-argillic brown earths have gleyic features attributable to intermittent waterlogging caused by a slowly permeable subsurface.

Major group—Podzolic soils

These are soils that have a podzolic B horizon.

Group—Brown podzolic soils. These are podzolic soils that have a Bs horizon containing significant amounts of amorphous iron and aluminium sesquioxides apparently accumulated in situ; E, Bh and Bf horizons are lacking and there is no Bg horizon starting above 40 cm. Typical brown podzolic soils have a distinct topsoil and lack gleyic features.

Major group—Surface-water gley soils

These are non-calcareous or decalcified soils that have gleyed subsurface horizons primarily attributable to seasonal saturation caused by slowly permeable subsurface horizons.

Group—Stagnogley soils. These soils have a distinct topsoil and are gleyed (grey or grey and brown mottled) within 40 cm of the surface. They lack pervious Cg or CG horizons and have slowly permeable Bg and/or BCG horizons. Typical stagnogley soils usually have Eg over Btg horizons. Pello-stagnogley soils have a clayey layer more than 30 cm thick starting at the surface or from the base of the plough layer and usually show shrink-swell phenomena in the form of slickensiding, or glazed ped faces (pelo-features). Btg horizons may or may not be present. Cambic stagnogley soils lack pelo-features and have no argillic B horizon. Paleo-stagnogley soils are stagnogley soils with paleo-argillic Btg horizons. Red mottles are evident in the subsoil.

Major group—Ground-water gley soils

These soils have gleyed subsurface horizons that are permeable or overlie permeable substrata, and in which gleying is attributable to the presence of a shallow fluctuating ground-water table.

Group—Cambic gley soils. These are loamy or clayey non-alluvial soils that are gleyed with 40 cm of the surface, have distinct (non-humose) topsoils and permeable Bg, BCg, Cg or CG horizons. Typical cambic gley soils normally have Bg horizons that are permeable and affected by high ground water. If slowly permeable Bg horizons are present permeable Cg or CG horizons occur within 1 m of the surface.

Group—Humic gley soils. These are analogous to cambic gley soils but with humose or peaty topsoils. Typical humic gley soils lack an argillic B horizon and have no calcareous substratum; usually permeable, loamy Bg and Cg, or BCg and CG horizons are normally grey or even bluish and strongly affected by groundwater.

Major group—Peat soils

These soils, formed under wet conditions occupy a few small patches. Due to their high base status they have been grouped as eutrophic, but not further differentiated in this district.

Soils developed in recent alluvium have been grouped as miscellaneous alluvial gley soils which includes loamy and peaty soils. All have a high ground-water table and peaty, humose and distinct topsoils occur.

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